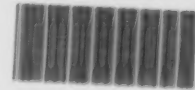


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PHASE II

Prepared For:

TRANSPORTATION
DEVELOPMENT CENTRE

Prepared By: **BCRAIL**

**BC RAIL
TRAIN CONTROL SYSTEM
TEST BED DEVELOPMENT
SYSTEM**

Amended August, 1987
January 1987

TP 8154E

BC RAIL TRAIN CONTROL SYSTEM (TCS)
TEST BED SYSTEM DEVELOPMENT

by

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BC RAIL

and

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Prepared for

Transportation
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JANUARY, 1987 (Amended August, 1987)

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The contents of this report reflect the views of the authors and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

Une sommaire en français de ce rapport est inclus avant la Table des matières.

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17. Résumé Ce rapport rend compte des travaux de la phase II du programme en quatre phases visant le développement et la mise en oeuvre d'une variante de système avancé de commande des trains qui fait appel à la transmission de données entre les postes de régulation, les trains et les équipes d'entretien. Cette phase II des travaux avait pour but d'augmenter la puissance de l'ordinateur central, d'établir une liaison de transmission de données formée de stations radio fixes et mobiles (embarquées) et de mettre tout le système à l'essai sur deux tronçons de voie, l'un non électrifié et l'autre électrifié sous 50 kV. Le système de commande envisagé est une variante du cantonnement par block manuel, mais où les communications vocales sont remplacées par des données numériques. Les instructions relatives à chacun des trains se trouvant à proximité sont affichées sur un écran disposé dans le poste de conduite. Pour la transmission qui s'effectue à 1 200 bits par seconde, on se sert d'un protocole à répétition automatique des messages non acquittés, avec délai aléatoire d'accès et détection de collision. Les messages délibérément courts, font appel à la numérotation, seul le numéro correspondant au message voulu étant transmis, accompagné de la partie variable des données. Les essais qui ont eu lieu sur le tronçon non-électrifié pendant plus de cent heures, et sur le tronçon électrifié durant une quinzaine d'heures, ont permis de démontrer l'efficacité et la fiabilité du système. Aucun des messages acquittés par le système ne contenait d'erreurs, sur les 60 000 transmissions effectuées, y compris les répétitions. De plus amples travaux restent nécessaires pour rendre le système plus résistant aux perturbations normales dans le contexte ferroviaire et pour qu'il puisse être accepté par les agents de régulation.			
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PREFACE

The work described in this report follows on from work performed previously and described in report TP 7269 E, "Evaluation of the Location, Identification and Control (L.I.C.) System in an Electrified Railway Environment", December 1985. That work developed certain design concepts intended to improve communication between dispatch-centre computers (the host) and computer equipment carried on-board trains (on-board train equipment). However, the host computer used was unable to support the new designs, so the concepts could not be field tested.

The present work is intended to extend the previous work by obtaining a new, more capable host computer and transferring the previously-developed programs to the new computer, enhancing the on-board train display to provide graphic (as well as alpha-numeric) display of information, extensively testing the mobile communication system, and demonstrating satisfactory operation in both MBS and electrified railway territory.

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SUMMARY

INTRODUCTION

The work described in this report has been performed as the second phase of a four-phased project to develop and implement a form of advanced train control using data transmission for communication between dispatchers, trains and track forces. This second phase has as its objectives:

- o Upgrade the dispatch host computer system to support the basic operations of an advanced train control system;
- o Provide a suitable system for communication between the host computer and trains, and test that system on two sections of track equipped as test beds (one of which is electrified territory with a 50,000 volt catenary);
- o Provide and install equipment for three radio base station sites (Site Control Units) and three locomotives (On-board Train Units);
- o Evaluate and report on the results obtained.

PROJECT METHOD

The train control system adopted is a modified form of manual block operation, in line with that now being proposed by the North American Advanced Train Control Systems (ATCS) project. It covers fixed-block operation, allowing trains to enter and exit blocks via a specified route and direction, with provision for protection of non-directional trains and other track forces, and for multiple occupancies within a block. Nineteen unique operating scenarios have been developed, with variations, to demonstrate and test the performance of the system.

The communication system is based on an hierarchical structure, with the host computer at the top of the hierarchy and supported by a communication Network Manager (NWM). Below the NWM are Cluster Control Units (CCUs), and below those are Site Control Units (SCUs). The SCUs communicate on the lowest level with On-board Train Units (OBTs). The SCUs and all higher levels are at fixed locations and are interconnected by microwave (in this case) or other point-to-point communication carrier. The OBTs are mobile, and communicate with the SCUs by mobile radio (UHF in this case). The communication links all operate at 1200 bits per second, a rate which is handled easily without having to modify the UHF mobile radios.

Work done previously had identified proper design of the mobile data link as a critical factor in achieving successful advanced train control. We developed a contention protocol based on the European Electronic Association (EEA) "Preferred Data Transmission System for Land Mobile Radio using Binary Format", modifying the format to add contention control and to provide error recovery by automatic re-transmission of unacknowledged messages (ARQ). That protocol enables us to handle relatively short messages (less than about 300 bits) effectively and reliably, and with greater efficiency than obtainable with more-sophisticated protocols which become necessary for longer messages.

To keep messages short, we developed a message catalogue, assigning a catalogue number to the basic format (fixed wording) of each of the standard messages used for dispatching trains and providing information to dispatchers and train crews. Messages transmitted then consisted only of the catalogue number and the variable data, and the receiving unit reconstructed the original complete message by retrieving the basic format from its catalogue.

The communication network, although it has some fixed physical links, makes use of "virtual paths" to establish communication between terminals using whatever paths are available. The virtual paths are set up by the system as required, and are transparent to the dispatcher and train crews.

EQUIPMENT

For the host computer we used two Digital Equipment Corporation (DEC) MicroVax II machines and several DEC colour display terminals. Two displays showed a graphic representation of the track layout and train positions, two other displays were used by the dispatcher for text input and output, and a fifth display (text) gave the dispatcher information on the status of the communication network. Program source code is "C", running under the VMS operating system.

For the communication network we used specially-built computer equipment based on the IBM PC/XT and PC/AT motherboards, with specially-designed modem boards added to provide the communication functions. On board each train the equipment included a Glenayre Digitrac interrogator and interrogator controller, an axle generator, and a high-resolution electro-luminescent flat-screen graphic display with an eight-key keyboard, all connected to the OBT. Program source code is "C", running under a proprietary operating system developed by the contractor for this application.

TEST RESULTS

We performed two sets of system tests; the first set in late 1986 on the southern test bed (approximately 40 miles (64 km) of track between North Vancouver and Squamish, B.C.), and the second set in May of 1987 on the northern test bed (approximately 3.5 miles (5.6 km) of track at Tacheeda, B.C.). The first tests demonstrated basic system functionality in a normal operating environment, the second set demonstrated functionality in an environment involving operation of electric engines powered from a 50,000 volt catenary.

On the southern test bed we achieved slightly more than 100 hours of train operation, involving about 15,000 echo-test messages (two transmissions per message) and close to 60,000 message transmissions (including retries). No messages were received with undetected errors (i.e., messages accepted and acknowledged by the system did not contain errors).

As expected, short messages rarely required retries for success; longer messages more-frequently required at least one retry for success. Also as expected, the channel error rate for communication to a stationary train was usually very low and required few if any retries even for long messages; however, the channel error rate rose dramatically when a train began to move, resulting in an increased retry rate for moving trains.

The communication results on the northern test bed were essentially identical to those for the southern test bed, with no noticeable influence from the electric train operations.

CONCLUSIONS AND RECOMMENDATIONS

The interrogator/transponder train location system (Digitrac) developed in previous work and used in these tests is effective and reliable. "Missed transponder" reports from previous work were the result of communication failures rather than transponder failures. Digitrac or its equivalent should be used for precise train location.

Short messages, achieved by the use of a message catalogue, are essential for successful data communication with moving trains, especially if an easy-to-implement code structure and protocol is to be used. Forward error correction is not necessary if messages are kept short so that an ARQ procedure is efficient. The EEA format, modified to provide contention control and error recovery, is satisfactory for advanced train control using short messages. More work should be done to upgrade the implementation of the EEA format and to select an improved method of contention control for the protocol.

Although a transmission rate of 1200 bits per second appears to be satisfactory for communication between trains and radio base sites, a significantly higher transmission rate is desirable on the remainder of the network, especially between the network manager and the host. That link is a bottleneck through which the total traffic of the system must pass. An X.25-like protocol on the main network and an Ethernet-like link between the host and the NWM are probably appropriate.

More work needs to be done on the on-board train cab display to improve the brightness and contrast ratio and to improve reliability.

The hardware used in this phase generally is prototype equipment. Although it served the purpose, considerable work is required to make it more tolerant of its electrical and mechanical environment before it could be considered for operational use on a railway.

RÉSUMÉ

INTRODUCTION

Ce rapport rend compte des travaux de la phase II d'un programme en quatre phases visant le développement et la mise en oeuvre d'une variante de système avancé de commande des trains qui fait appel à la transmission de données entre les postes de régulation, les trains et les équipes d'entretien. Cette phase II avait pour but:

- o d'augmenter la puissance de l'ordinateur central afin qu'il puisse prendre en charge les principales opérations du système;
- o d'établir une liaison de transmission de données appropriée entre l'ordinateur central et les trains et de mettre ce système à l'essai sur deux tronçons de voie, dont l'un est électrifié sous 50 kV;
- o de fournir et d'installer le matériel nécessaire en vue d'établir trois stations radio fixes et trois stations mobiles (embarquées);
- o d'évaluer le système complet et d'en rendre compte.

DESCRIPTION

Le système de commande retenu est une variante du cantonnement par block manuel, conformément à ce qui est proposé par les concepteurs du système avancé de commande des trains sur le réseau ferroviaire en Amérique du Nord. Il fonctionne à canton fixe, autorisant les trains à occuper et à quitter un canton dans une direction donnée et assurant une protection par rapport aux trains bidirectionnels, aux équipes d'entretien et, aussi, dans certains cas exceptionnels, à l'occupation multiple d'un même canton. Dix-neuf scénarios ont été élaborés qui, avec des variations, ont servi à vérifier et à essayer la performance du système.

Le système de communication adopté est de type hiérarchique, le principal élément étant un ordinateur central soutenu par des Unités de gestion de réseau (Network Manager) qui gèrent des Unités de commande de grappe (Cluster Control Units) lesquelles pilotent des Unités de commande locale (Site Control Units) celles-ci, au bas de l'échelle, communiquant avec les Unités embarquées (On-Board Train Units). Toutes ces unités, sauf les dernières, sont de type fixe, interconnectées soit par des ondes décimétriques (comme c'est le cas ici), soit par tout autre type de liaison point à point. Les Unités embarquées, par définition mobiles, communiquent avec les Unités locales par des équipements radio mobiles (fonctionnant en UHF en ce qui nous concerne). Le débit est de 1 200 bits par seconde qui convient à toutes les unités, y compris celles qui sont mobiles.

Les travaux antérieurs avaient montré que la radiocommunication mobile était l'élément critique dans le système de commande envisagé. Il a donc fallu étudier une procédure de contrôle de liaison dérivée du protocole standard de l'Electronic Engineering Association "Preferred Data Transmission System for Land Mobile Radio Using Binary Format", mais avec, en plus, détection de collision et correction des erreurs par la répétition des messages non acquittés. Ce protocole permet de transmettre des messages relativement courts (moins de 300 bits) avec plus d'efficacité et de fiabilité que dans le cas des protocoles plus sophistiqués nécessaires lorsque les messages sont longs.

La concision des messages a été obtenue grâce à un système de numérotation, où les messages standard dans leur forme de base (nombre de bits invariable) reçoivent un numéro, de sorte que pour commander les trains et informer leur équipage de conduite, il suffit de transmettre le numéro des messages voulus auxquels on adjoint la partie variable du message. À la réception, ces messages sont restitués automatiquement et dans leur intégralité.

La liaison, en plus des circuits physiques nécessaires, s'établit selon les besoins, à travers des circuits virtuels, la connexion étant transparente aussi bien pour l'agent régulateur que pour les équipes de conduite.

ÉQUIPEMENTS UTILISÉS

Le contrôle central se fait par deux ordinateurs MicroVax II de Digital Equipment Corporation et de plusieurs écrans couleurs de même fabrication. Deux écrans servent à afficher graphiquement le tronçon de voie et la position des trains qui l'occupent, deux autres servent à l'agent régulateur pour lancer et recevoir des messages, un cinquième renseigne l'agent sur l'état du réseau de communication. Le langage utilisé est le langage "C", géré par un système d'exploitation VMS.

Pour les liaisons, les équipements utilisés étaient dotés de cartes-mères dérivées de celles équipant les PC/XT et PC/AT d'IBM, en plus des modems nécessaires. À bord des trains se trouvaient un interrogateur et sa commande de Glenayre Digitrac, un alternateur d'essieu et un moniteur à écran plat, haute résolution et à diodes électroluminescentes avec son clavier 8 touches, le tout étant en communication avec l'unité embarquée. Là aussi, le langage "C" était utilisé, géré par un système d'exploitation réalisé exprès par le contractant.

RÉSULTATS

Deux séries d'essais ont été effectuées en Colombie-Britannique: d'abord, sur un tronçon long d'une quarantaine de milles entre North Vancouver et Squamish, vers la fin de 1986; puis, sur un tronçon de 3 milles et demi environ, à Tacheeda, en mai 1987. Les premiers ont mis en évidence les caractéristiques fonctionnelles du système sur locomotives diesel, les seconds, dans un contexte ferroviaire électrifié fonctionnant sous 50 kV.

Durant la centaine d'heures ou plus d'essais sur des trains diesel, quelque 15 000 contrôles par écho (deux transmissions par message) ont été faits sur près de 60 000 transmissions, répétitions comprises. Aucun des messages acquittés par le système ne contenait d'erreurs.

Comme prévu, les messages délibérément courts ont rarement dû être répétés, tandis que les messages plus longs ont nécessité au moins une répétition. Également prévu, le taux d'erreur dans la transmission vers un train immobile a été très faible, nécessitant peu ou pas de répétition même dans le cas de messages longs; toutefois, dès que le train commençait à s'ébranler, ce taux d'erreur augmentait énormément de même que le taux de répétition lorsque le train roulait.

Les résultats obtenus lors de cette deuxième série d'essais ont été essentiellement identiques à ceux de la première série, montrant que l'influence d'un contexte d'électrification peut être tenue pour négligeable.

CONCLUSIONS ET RECOMMANDATIONS

Le système de localisation des trains (système Digitrac) par interrogateur-transpondeur utilisé dans la présente étude s'est révélé fiable et efficace. Les pannes de transmission dont il a été fait état dans les travaux antérieurs sont attribuables à la liaison et non au transpondeur. Il est recommandé d'utiliser ce système, ou un système équivalent, pour la localisation précise des trains.

Les messages destinés à un train en marche doivent être courts et faire appel à la numérotation, surtout si un code et un protocole de transmission de mise en oeuvre simple sont utilisés. La correction d'erreur sans voie de retour n'est pas nécessaire lorsque le message est tenu assez court pour que la répétition automatique des messages non acquittés soit efficace. Le protocole standard de l'EEA, avec détection de collision et correction des erreurs, donne de bons résultats si les messages restent courts. De plus amples recherches seront cependant nécessaires pour élargir le protocole EEA et lui adjoindre une méthode de détection de collision plus efficace.

Bien que le débit fixé à 1 200 bits par seconde convienne à la liaison entre les trains et les stations fixes, un débit plus élevé devient désirable pour les autres liaisons, notamment celle entre l'unité de gestion de réseau et l'ordinateur central, qui constitue un passage obligé. Un réseau dérivé du type X.25 pour la liaison train-stations et un réseau dérivé du type Ethernet pour la liaison unité de gestion-ordinateur central semblent les plus appropriés.

L'écran d'affichage dans le poste de conduite des trains devrait être amélioré, du point de vue luminosité, contraste et fiabilité.

Enfin, si le matériel qui a servi aux essais a bien fonctionné, il n'en est pas moins au stade de prototype. Pour le perfectionner et l'amener au stade opérationnel dans le contexte ferroviaire normal, il faudra le rendre moins sensible aux perturbations électriques et mécaniques.

GLOSSARY

This Glossary of Abbreviations, Acronyms and Symbols is provided to assist the reader to understand the text which follows.

AAR	Association of American Railways.
ALN	Assign Logical Name - a message sent to a train to assign a logical identification name to the train and its OBT. Sent when the train is first logged onto the system.
ARBE	Authority Response to Request for Block Entry - a message sent from a train in response to an RBE, to signify acceptance or rejection of the RBE.
ARRI	Authority Response to Recant Issued Authority - a message sent from a train in response to an RIA, to signify acceptance or rejection of the RIA.
ARRN	Authority Response to Recant with New Authority - a message sent from a train in response to an RNA, to signify acceptance or rejection of the RNA.
ATCS	Advanced Train Control Systems - a system or group of systems presently under development as a joint project of the Canadian Railway Association and the Association of American Railways.
BCN	Backbone Communication Network - the communication network which connects all of the mobile radio repeater sites to the dispatch centre. In the present case, this network consists of voice--bandwidth multiplex channels carried over microwave.
BEA	Block Entry Authority - a message sent to a train to deliver authority for occupancy of one or more blocks of track.
bps	Bits per second - a measure of communication data rate.
Byte	A term used to refer to a group of 8 bits of data, which is sufficient to define one alpha-numeric character in most codes.
CIA	Conflict with Issued Authority - a message sent from a train when the OBT detects a conflict between a new authority and a previous authority.
CTRN	Cancel Train - a message sent to a train to cancel its supply, and thus to remove it from the system.

ECM	Emergency Check Message - (not fully implemented) a message sent from a train when an emergency situation is detected; e.g., when the engineman pushes the Emergency button, or when a train enters a block for which it does not have authority.
GDU	Graphic Display Unit - the display unit carried on board a train, associated with (controlled by) the OBT.
Kbyte	Kilobyte - one thousand bytes, a measure of computer memory capacity.
LIC	Location, Identification and Control - a train control system developed by BC Rail prior to this work. Not accepted at an operational level.
Mbps	Megabits per second - million bits per second, a measure of communication data rate.
Mbyte	Megabyte - one million bytes, a measure of computer memory capacity.
MCN	Mobile Communication Network - the communication network made up of a radio repeater and the mobile radio units carried on board trains within the communication coverage area of the repeater.
NWM	Network Manager - the logic and communication control unit located at the central dispatch site, which manages all communication between the host computer and the SCU's and between the SCU's on the backbone communication network.
OBT	On-board Train equipment - the logic and communication control unit which contains the main message processor and the communication processors carried on board the train.
PCC	Position Change Clear - a message sent from a train to indicate that it has cleared a block of track (crossed a pair of transponders, with unidirectional authority).
PCE	Position Change Entry - a message sent from a train to indicate that it has entered a block of track (crossed a pair of transponders).
PCU	Position Change Update - a message sent from a train to indicate that it has changed its position by a unit increment of distance from the last transponder crossing.
RAC	Railway Association of Canada.
RBE	Request for Block Entry - a message sent to a train which has authority for a block of track, requesting permission for another train to enter the block.

RIA	Recant Issued Authority - a message sent to a train to cancel authority for occupancy of one or more blocks of track.
RNA	Recant with New Authority - a message sent to a train to change the authority for occupancy of one or more blocks of track.
RVP	Request for Virtual Path - a message sent from the Host to the NWM, requesting that a virtual path be set up between the Host and the identified terminal.
SCM	Status Change Message - initiated when a train enters or clears a block.
SCU	Site Control Unit - the logic and communication control unit located at a radio repeater site, which controls the repeater radio and handles all communication between the backbone communication network and the mobile radio network served by the repeater.
TEXT	Text Message - a message sent in free-form text, containing up to 80 characters (including spaces).
UCI	Update Control Information - a message sent from a terminal or node to a lower terminal or node, preceding data intended to be used to up-date control information at the lower level.

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TABLE OF CONTENTS

1.	INTRODUCTION	1
2.	OBJECTIVE	1
3.	WORK PERFORMED	3
3.1.	<u>Background</u>	3
3.1.1.	Design Concept.	3
3.1.2.	System Configuration.	3
3.1.3.	Sub-system Configuration.	4
3.1.4.	Communication Protocols.	4
3.2.	<u>Upgrading the Host Computer Hardware</u>	6
3.2.1.	Selection of Equipment	6
3.2.2.	Installation and Test of Equipment	6
3.3.	<u>Upgrading the Host Computer Software</u>	8
3.3.1.	Reviewing the Operating Scenarios	8
3.3.2.	Porting Developed Software to the New System	8
3.3.3.	Developing New Software	9
3.3.4.	Communication between Modules.	11
3.4.	<u>Providing an Enhanced Communication Network</u>	11
3.4.1.	Communication Protocols	13
3.4.2.	Network Manager/Cluster Controller	13
3.4.3.	Cluster Control Units	15
3.4.4.	Site Control Units	15
3.4.5.	Signal Profile Mapping Function	17
3.4.6.	Signal Qualifying Function for Locomotives and Site Control Units	18
3.5.	<u>Vehicle Equipment, Hardware and Software</u>	18
3.5.1.	Conflict and Management Processor	18
3.5.2.	Communications Processor	20
3.5.3.	Central Interfaces Module	20
3.5.4.	Graphics Display Unit	23
3.6.	<u>Conducting Shop Tests</u>	25
3.6.1.	Network Manager/Cluster Controller	25
3.6.2.	Site Control Units	26
3.6.3.	On-board Train Units	27
3.6.4.	System Integration	28
3.6.5.	Preparation of Reference Manuals	28
3.6.6.	Preparation of Operator Manuals	28
3.7.	<u>Conducting Field (On-site) Tests, Squamish Subdivision</u>	28
3.7.1.	Test Procedure	29
3.7.2.	SCU to NWM Communication	30
3.7.3.	Locomotive to SCU Communication	30
3.7.4.	NWM to Host Communication	30
3.7.5.	System Communication excluding the Host	31
3.7.6.	Total System Communication	31

3.8.	<u>Conducting Field (On-site) Tests, Electrified Territory . . .</u>	32
3.8.1.	<u>Test Procedure</u>	32
3.8.2.	<u>Locomotive to SCU Communication</u>	34
3.8.3.	<u>Total System Communication</u>	34
3.9.	<u>Corrective and Preventive Maintenance</u>	34
3.10.	<u>Hardware Production Drawings, Software Manuals and Source . .</u>	34
3.11.	<u>Slide Presentation</u>	35
4.	OBSERVATIONS	35
5.	CONCLUSIONS	36
6.	RECOMMENDATIONS	37
6.1.	<u>Upgrade the Protocol Implementation</u>	37
6.2.	<u>Upgrade the Host/NWM Communication Link</u>	37
6.3.	<u>Upgrade the Backbone Communication Link</u>	38
6.4.	<u>Upgrade the Communication and Train Sub-systems Hardware . .</u>	38
6.5.	<u>Improve the Graphic Display Unit and Engineman's Keyboard . .</u>	38

LIST OF FIGURES AND PLATES

Figure 1	System Block Diagram	5
Plate 1	CRT Monitors and Keyboards in Dispatch Office	7
Figure 2	Host Software Modules	10
Figure 3	Host Software Modules, Illustrating Mailboxes	12
Figure 4	Network Manager Block Diagram	14
Figure 5	Site Control Unit Block Diagram	16
Figure 6	On-board Train Processor Block Diagram	19
Figure 7	Communications Processor Block Diagram	21
Figure 8	On-board Train Sub-system Block Diagram	22
Figure 9	Graphic Display Unit Face Layout	24
Figure 10	Transponder Layout for Northern Test Bed	33

APPENDICES

Appendix A	Conclusions from Phase I, TP 7269E
Appendix B	Photographs of CRT Displays, Dispatch Centre
Appendix C	Operating Scenarios, for Train Control System Tests
Appendix D	List of Host Sub-system Messages and Abbreviations
Appendix E	Set of Six Typical Signal-quality Histograms



1. INTRODUCTION

The work described in this report has been performed under Supply and Services Canada Contract No. O8SB.T8200-5-5574, jointly funded by the Transportation Development Centre of Transport Canada and by BC Rail.

This work follows on the work of an earlier contract, DSS No. OSB8300323. Under that contract, new design concepts for ATCS were developed as advancements over the LIC system originally tried by BC Rail during 1979-1984, in an attempt to overcome the major shortcomings of the LIC system. Although the new concepts seemed promising, the "host" computer used to implement the central dispatch functions proved inadequate for the job and the work was terminated without field testing. The present project is intended to provide a suitable test bed to permit satisfactory implementation and field testing of the concepts developed previously.

The BC Rail Train Control System has been designed to implement most of the functions of a Level 30 ATCS. The Phase II system provides a fall-back mode which approximates a Level 10 system for non-equipped trains, and as a backup in case of data communication system failure.

2. OBJECTIVE

The original objective of this work is set out in the Work Statement of the contract, included as Appendix A. That work statement may be paraphrased as:

- o Upgrade host computer hardware and software to support adequately the basic operations of an advanced train control system.
- o Provide an enhanced system for communication between host and trains operating over a section of railway able to operate under modified MBS rules, and over a section of electrified railway, the system to include:
 - Three remote radio sites to be installed on the BC Rail Squamish subdivision
 - A network manager/cluster controller to be installed at North Vancouver, communicating with the three remote sites and with the host computer
 - A signal profile mapping function to provide for a systematic record of the signal quality profile along the subdivisions under test
 - A signal qualifying function to allow the locomotive OBT to initiate communication from a given location based on a known rate of successful transactions from that location.

- o Provide and install locomotive equipment (OBT and associated equipment) aboard three vehicles, complete with:
 - Communications processor
 - Conflict and management processor
 - Central interfaces module
 - Graphics display unit of military quality
- o Conduct shop tests in order to certify proper operation prior to field (on-site) testing. In preparation for field testing, prepare reference manuals for:
 - Network Manager/Cluster Controller (NWM)
 - Site Control Unit (SCU)
 - On-board Train Unit (OBT)

and operator manuals for:

 - Train Operator (OBT)
 - Dispatch Operator (Host)
- o Conduct field tests (on-site tests) and demonstrate satisfactory operation. Test the system using the first 42 miles of the Squamish subdivision and all three equipped vehicles, then test the system on a part of the Tumbler subdivision. Test the new graphic display unit throughout the test period. On completion of field tests, demonstrate satisfactory operation of the system.
- o Provide all corrective and preventive maintenance for the duration of the contract, including the period of the tests.
- o Prepare and submit to TDC five copies of hardware production drawings and of software manuals including source listings of host software.
- o Prepare and submit to TDC technical reports on the work carried out and on the results achieved.
- o At the conclusion of the work, present to TDC and to the steering committee a slide presentation on the work carried out and on the results achieved.

3. WORK PERFORMED

3.1. Background

In 1985, following earlier experience with attempts at advanced train control, and encouraged by establishment of the North American Advanced Train Control Systems (ATCS) joint task force of the AAR and RAC, we undertook renewed work on the BC Rail Train Control System. We reported on Phase I of that work in Document TP 7269E, "Evaluation of the Location, Identification and Control (L.I.C.) System in an Electrified Railway Environment", December 1985, with conclusions as given in Appendix B. Those conclusions led to the statement of work referred to under Objective (section 2).

In this background section we will discuss some of the design decisions made in Phase I and carried through into this Phase II work. New designs, or changes to previous designs, will be discussed under the appropriate sections describing Phase II.

3.1.1. Design Concept.

At the outset of this Phase II we prepared two conceptual design documents based on the Phase I work: "BC Rail Train Control System Development Conceptual Design", draft issue #2 dated January 20, 1986; and "NKG-BCR ATC Conceptual Design Specification (Communications and Field Unit Subsystems)", draft dated January, 1986. Those documents are available for inspection on request.

3.1.2. System Configuration.

The system configuration we described in the conceptual documents is simple, just sufficient to demonstrate satisfactory operation of the communication system and equipment. It covers a fixed-block operation with controlling instructions allowing directional trains to enter and exit blocks via a specified direction and route, with provision for protection of non-directional trains and track maintenance-of-way crews, and for multiple occupancies within a block. Multiple occupancies include such situations as three- and four-train meets and overtakes at a siding, track work programs involving combinations of work trains and track gangs, and possibly two auxiliaries working within the same limits. Twenty-one operating scenarios were defined to be dealt with by the system. Two of those scenarios were actually minor variations of other scenarios, so nineteen of the scenarios were carried through to the Phase II system test.

3.1.3. Sub-system Configuration.

The sub-system configuration is based on an hierarchical structure, with a Host computer at the dispatch centre, connected to a communications Network Manager (NWM) co-sited with the Host. Below the NWM in the hierarchy are Cluster Control Units (CCU), and below those are Site Control Units (SCU). At the lowest level, served by the SCU, are the On-board Train units (OBT).

Figure 1 is a block diagram of the system.

The NWM, CCU's and SCU's are connected by physical circuits derived from existing communication facilities; microwave channels in the present case. We refer to these circuits as the backbone (or backhaul) communication network, abbreviated to BCN.

Each SCU controls a radio base station, and communicates with OBT units via available data radio channels; UHF channels in the present case. We refer to the radio channel served by each SCU as a mobile communication network, abbreviated to MCN.

A group of SCU's (e.g., those serving a sub-division) may share a common channel to their serving CCU. CCU's may share a common channel to the NWM. If there is only one group of SCU's (as for the test bed), there is no need for a CCU; the NWM can perform the necessary functions alone.

3.1.4. Communication Protocols.

In Phase I we considered the relative merits of polling and non-polling (contention) communications protocols, and concluded that a contention protocol was most appropriate for the MCN. We developed a protocol based on the European Electronic Association (EEA) "Preferred Data Transmission System for Land Mobile Radio using Binary Format", modifying the format to add contention control and to provide error recovery by automatic re-transmission of unacknowledged messages (ARQ).

The developed protocol is described in document TP 86-103 BCR "Proposed Protocol for use in Advanced Train Control Systems for North American Railroads", available on request.

We concluded that a polling protocol was most appropriate for the BCN, although a contention protocol could be used if communication traffic is light or is concentrated on a few site controllers. We planned to use an X.25 packet-transmission protocol, an international standard which is widely accepted for data transmission over distributed networks.

Key:

- CCU Cluster Control Unit
- Host Host (central) computer
- NWM Network Manager
- OBT-LP On Board Train Locomotive Processor
- SCU Site Control Unit
- BCN Back-bone Communications Network
- CSS Central Sub-System
- MCN Mobile Communications Network
- OBT On Board Train sub-system

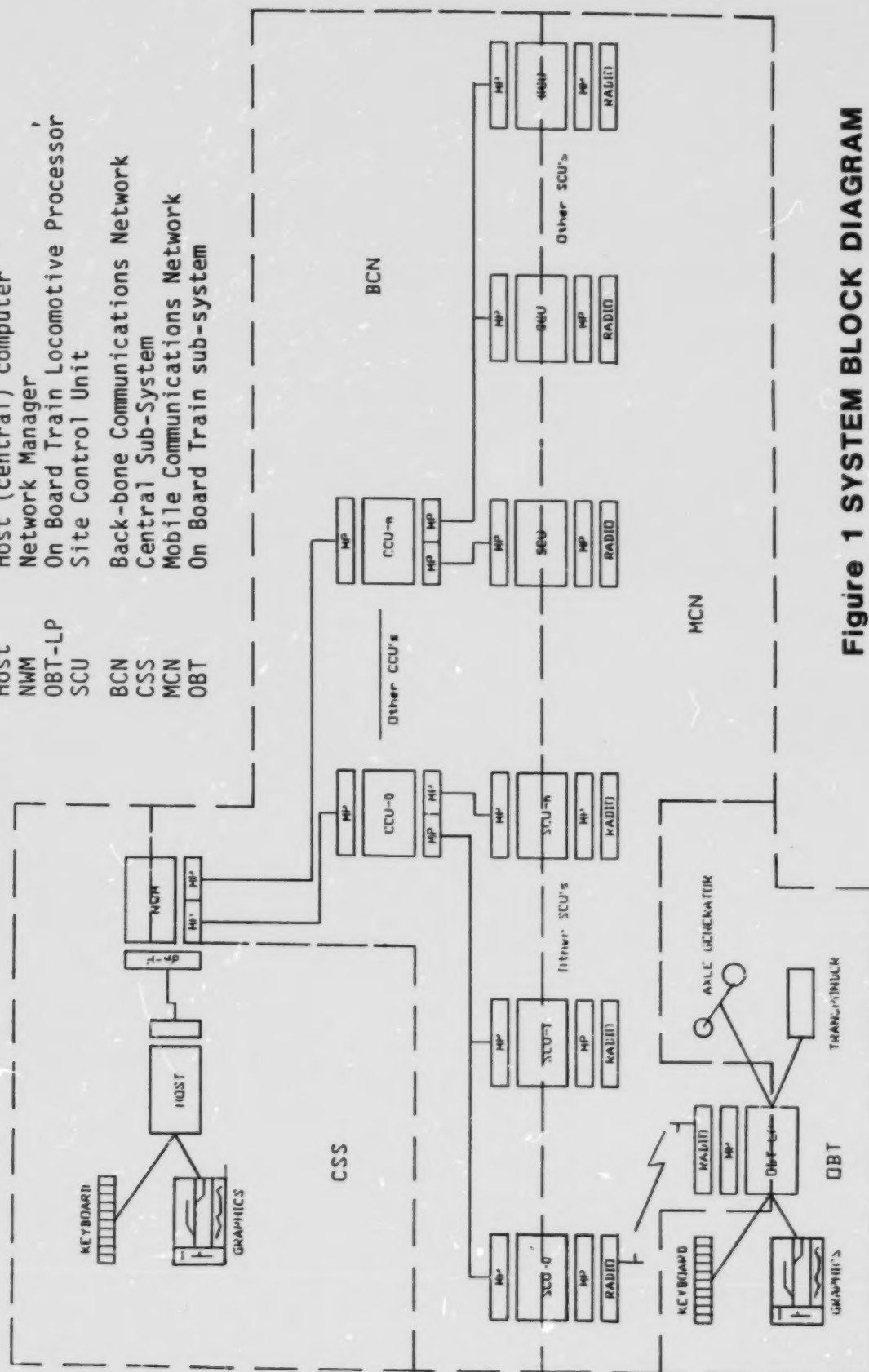


Figure 1 SYSTEM BLOCK DIAGRAM

3.2. Upgrading the Host Computer Hardware

The host computers used for Phase I were Digital Equipment Corporation PDP-11/44 16-bit processors, using the Ultrix-11 operating system. That combination turned out to be unsatisfactory for train control because of limitations of operating speed, memory size, and data transfer capability between programs. In Phase II we have overcome those limitations by purchasing a new host computer and using a different operating system.

3.2.1. Selection of Equipment

For the host computer we chose two machines, both of which are versions of the Digital Equipment Corporation MicroVax II family. DEC computers were chosen in the first instance to maintain compatibility with the existing DEC computing equipment used throughout the BC Rail system. The Vax machines also have an excellent reputation for use in program development, and can be obtained with proven support software for that purpose.

The two machines are configured as follows:

- A. 9 Megabyte RAM, 73 Megabyte hard disk, TK50 tape backup, 16 serial terminal ports, dual 5-1/4-inch floppy-disk drives, Ethernet interface card.
- B. 5 Megabyte RAM, 10 Megabyte hard disk, 8 serial terminal ports, dual 5-1/4-inch floppy-disk drives, Ethernet interface card.

In addition to the main processors, we purchased two VT241 colour graphic terminals with drivers, one VT100 monochrome maintenance terminal, one LA120 terminal printer, and one DENLI Ethernet driver and receiver unit. We used a third VT241 terminal which was part of the Phase I computer equipment. During the course of the work, we leased three additional VT241 colour graphic terminals and drivers.

3.2.2. Installation and Test of Equipment

Initially we installed the processors and peripheral equipment at workstations within the BC Rail communications department, where the program development and documentation work was performed. When programming was completed, the processors and the maintenance terminal were installed in the communications site room in the BC Rail headquarters building, and the colour graphics terminals were installed in a room in the dispatch-office area.

Plate 1 shows the arrangement of CRT monitors and keyboards in the TCS dispatch office. Appendix C includes additional photographs of several CRT displays provided by the Host sub-system.



PLATE 1 - DISPATCHER CONSOLE

The equipment was effectively tested during the program development stage, and further tested during the system integration, shop test, and field test stages. We did not perform additional tests of the host computer hardware, since it is a standard product not specific to this project.

We experienced three failures of the colour terminals or their drivers, and one failure of the 73-Megabyte hard disk, over the period of approximately ten months of operation.

The Ethernet cards and DENLI drivers and receivers proved to be of value only for interconnecting the two Vax machines, and not for Host/NWM communication as we had intended. DEC's Ethernet software only provided support for 10-Mbps communications, whereas readily-available "Ethernet-compatible" hardware for the NWM could only support 1-Mbps communication. We purchased DEC DVP-11 synchronous-communication hardware, then found that DEC had no software available to support it. Thus, we were reduced to using the DEC asynchronous communication ports for network communication.

3.3. Upgrading the Host Computer Software

With the new hardware, we purchased a licence to use the DEC VMS operating system. This operating system provides strong support for program development and documentation; unfortunately, it does not provide an entirely satisfactory environment for real-time application operations, as discussed in Section 4.

3.3.1. Reviewing the Operating Scenarios

We developed nineteen operating scenarios, described in Appendix D, to demonstrate the features of the train control system. All the scenarios can be performed successfully except 6.3 (changing a lead engine number on an authorized train) and 6.6 (revising a train's authority for switching purposes). To accomplish 6.3 would require a significant change to the system software, not warranted in this phase; 6.6 can be accomplished, but not in a manner which is suitable in an operational environment; thus, it will have to be revised at a later date.

3.3.2. Porting Developed Software to the New System

The software developed under Phase I consisted of five modules: the host network manager, the command manager, the network communications interface, the dispatch communications interface, and a debugger/simulator. Some of the communications network management function was within the host, as well as in the network manager itself; thus, the software interface was not "clean".

The major problem with the host (hardware and software) in Phase I had to do with inter-process communication and synchronization. Ultrix-11 does not allow the use of common storage areas (mailboxes); information between processes must be 'piped'. Pipe size was limited to 4K bytes, and pipes operated as sequential files, so that information was no longer available after being read. Also, Ultrix-11 allowed only 21 file descriptors; barely enough for a basic system, and not enough to permit expansion with desirable additional processes or features.

Although the application software from Phase I was written in "C" and could be ported directly to the new Host computers, we found that we could not take proper advantage of the features of the new computers without rewriting the programs extensively. In effect, new programs were written, instead of simply porting the existing programs. We also decided that the communications network functions should be moved out of the host and placed entirely within the Network Manager, to provide a clean interface. These additional programming efforts were not included in the project plan, nor was the associated effort for documentation and debugging, with the result that both the schedule and the budget suffered.

3.3.3. Developing New Software

The Host software now consists of seven major modules, as described in the following paragraphs and illustrated in Figures 2 and 3.

3.3.3.1. DISP - Dispatcher. The DISP module presents a set of command menus to the dispatcher, and accepts commands from the dispatcher for use by the system. The commands are arranged in levels, as branches of a tree structure. Through the menus the dispatcher can supply trains, issue, cancel and revise authorities, send pre-formatted or free-form text to trains, deal with communication errors, and list trains supplied to the system.

3.3.3.2. COMMS - Communications. The COMMS module presents the dispatcher a list of communication problems, if any, and a communication status table on one of the system CRT displays.

3.3.3.3. CMDM - Command Manager. The CMDM module processes commands sent to it by the DISP and NETR modules, and checks for validity. This module also contains the Host system data base.

3.3.3.4. NETR - Network Router. The NETR module sends copies of commands to the appropriate modules. Commands are processed through a first-in-first-out queue.

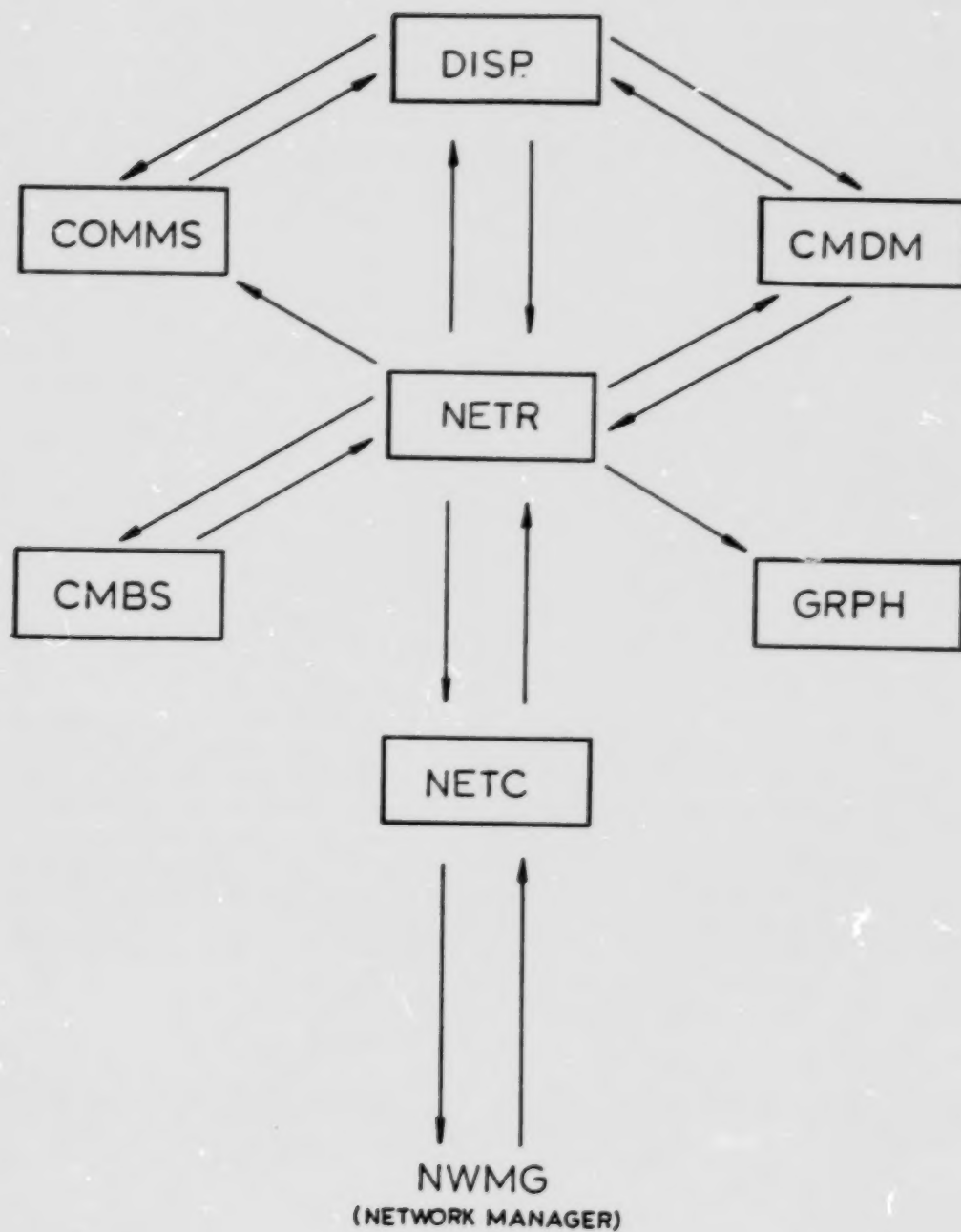


Figure 2

3.3.3.5. NETC - Network Communications. The NETC module is the link between the Host and the communications network (the Network Manager). Within the Host, messages are formatted for the Command Queue Structure; within the communications network messages are formatted as packets. The NETC module converts messages from either format to the other as required.

3.3.3.6. GRPH - Graphics. The GRPH module displays the track layout the main line and up to six sidings or additional trackage. Block boundaries are shown, and the current position, movement, and authority of each train, maintenance-of-way unit, and work gang is shown. Block names are shown, and the name and direction of each train are shown.

A colour convention has been adopted to show the current state of each block of track. For example, a double red line is an emergency situation, such as a block violation by a train or other equipped unit.

3.3.3.7. CMBS - Computerized Manual Block System. The CMBS module displays instructions for trains which are not equipped with an operational On-board Train unit. These instructions must be transmitted to the train by the dispatcher using voice radio. As the instructions are read back and confirmed by the dispatcher, he can underline the text on the screen, and the system will log the instruction and confirmation.

3.3.4. Communication between Modules.

Modules communicate with each by means of "mailboxes", areas of memory into which incoming messages can be deposited without immediately interrupting the receiving program. A module originating a message sets up a command queue structure and sends it to the mailbox of the destination module. Periodically the destination module checks its mailbox and retrieves and processes any messages found there. Figure 3 illustrates mailbox communication.

Appendix E contains a list of system messages and abbreviations.

3.4. Providing an Enhanced Communication Network

In the L.I.C. system all communication network "intelligence" was concentrated at the interface to the Host computers. In the present system, the intermediate and terminal nodes of the communication network can function somewhat independently if necessary. This reduces the communication traffic in some cases, reduces the signal processing load on the network manager in other cases, and makes the system generally more robust. The present system provides for "virtual paths" between communicating nodes, such that the actual message path may be different than the apparent, or virtual, path. In this way, communicating terminals do not need to be concerned with the actual route which a message may take between source and destination - the network will find an appropriate path and will use it.

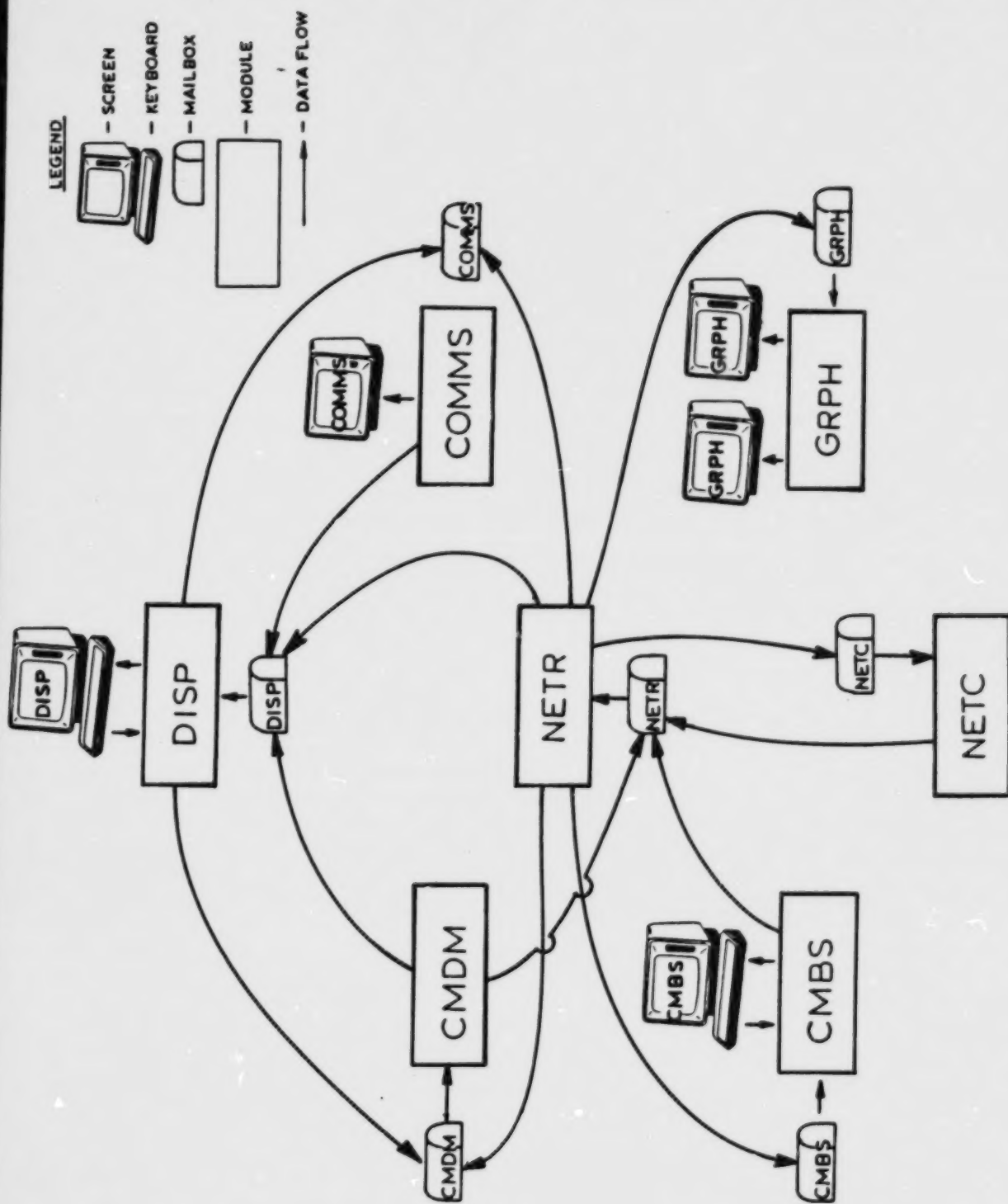


Figure 3

3.4.1.~ Communication Protocols

The mobile communication protocol developed under Phase I has been used in this Phase II work, and has been a significant contributing factor to our achievement of successful mobile data communication. There are several other protocols which might have been used, many of which use more-sophisticated encoding schemes and some of which use forward-error-correcting (FEC) codes. If free-form text messages had been the norm in this system, as it was for L.I.C. and is proposed by some to be for ATCS, a powerful FEC code would have been required. However, by using mainly standard messages from a limited catalogue we have managed to keep messages short and can use a simpler code and protocol effectively.

At the outset of Phase II we had intended to use an X.25-like protocol on the backbone communication network. When the extra programming effort required to rewrite the Host and communications sub-system programs drained our resources unexpectedly, we abandoned the X.25 design effort and resorted to using the same protocol on the backbone as on the mobile network. The communication bit rate is also the same (1200 bits/second). This has been satisfactory for our limited test-bed system, although we recognize the need for a higher data rate and a more-suitable protocol in an operational system.

3.4.2. Network Manager/Cluster Controller

The Network Manager (NWM) consists of a 16/32-bit main processor (similar to an IBM PC/AT) equipped with communication interface cards to allow it to communicate with the Host computer and with lower-level units on the backbone communication network. Figure 4 is a block diagram of the NWM.

The NWM performs the following tasks:

- o Communicates with the Host computer.
- o Determines the route for messages and retransmits these messages to the appropriate communication node or to the Host.
- o Changes fixed-station and mobile-station message routing as new communication routes are added or existing routes are changed or removed.
- o Initiates a "mobile seek" function to establish a virtual path to a mobile unit if that unit is not found via the expected communication route.
- o Coordinates recovery from error for all lower-level nodes or terminals of the network.
- o Maintains a master copy of the track signal quality profile.
- o Maintains a master library of all communication system software.

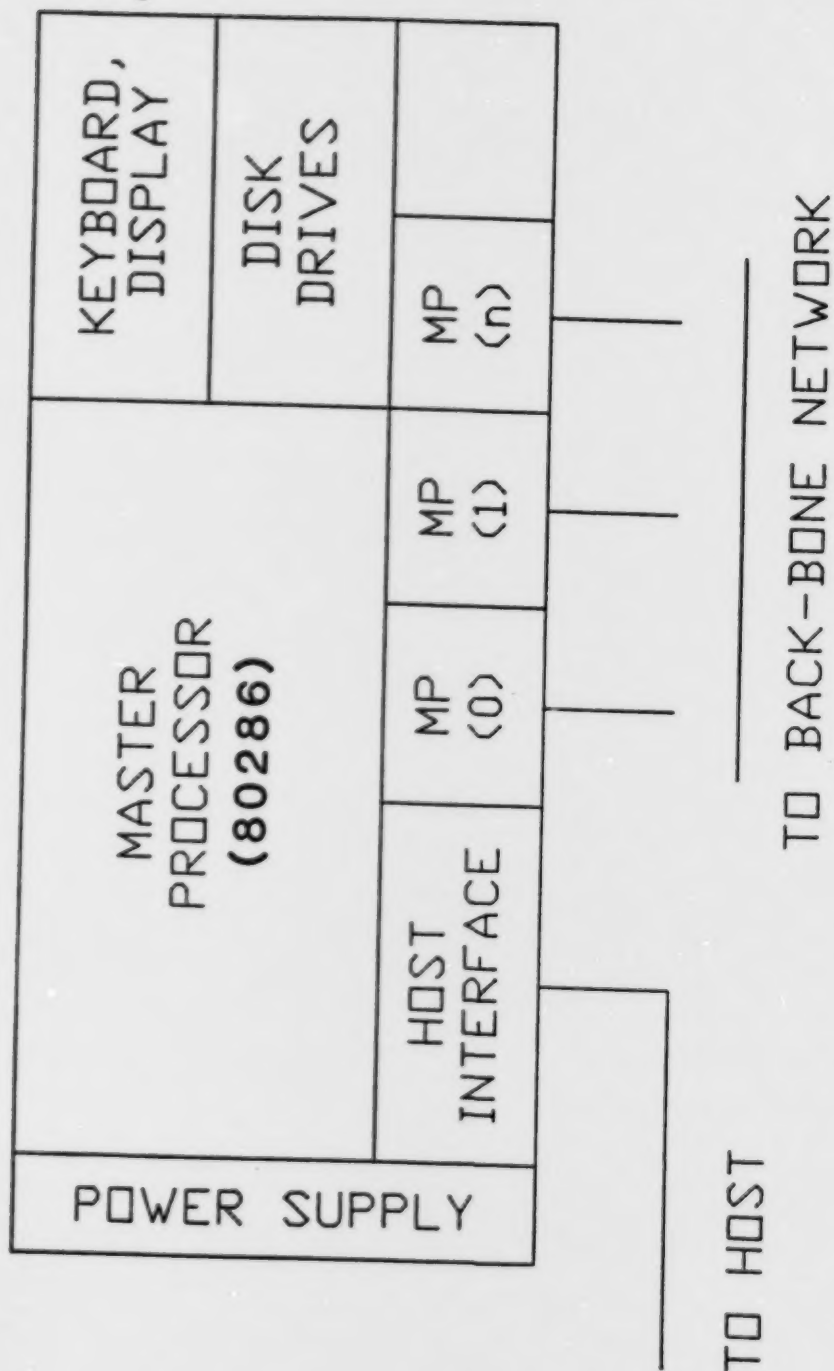


Figure 4 NETWORK MANAGER BLOCK DIAGRAM

- o Coordinates "broadcast" messages and ensures that all terminals acknowledge broadcasts.
- o Performs routine background diagnostics on the communication network, and coordinates diagnostic functions of other units.

3.4.3. Cluster Control Units

In a large network, covering several subdivisions for example, it will be desirable to provide some diversification and isolation between groups of SCU's so that they can function relatively independently. The system anticipates that configuration by providing for the use of Cluster Control Units (CCU's) to which each group of SCU's will communicate, with the CCU's all communicating with the NWM.

The test-bed system has only four SCU's, so the function of CCU is not needed and has not been implemented.

3.4.4. Site Control Units

The Site Control Unit (SCU) used in Phase II is a new design, replacing the remote terminal unit installed for Phase I.

The SCU consists of a 16-bit main processor similar to an IBM PC/XT, equipped with additional communication interface cards. These cards allow it to communicate with other units on the backbone network, and to control a co-sited radio base station and communicate with other units on the mobile communication network. It has sufficient "intelligence" to control contention on the mobile network, to handle error recovery on either the backbone or the mobile communication networks, and to maintain a record of mobile communication signal quality within its coverage area. Figure 5 is a block diagram of an SCU.

The SCU performs the following specific tasks:

- o Communicates with the NWM via the backbone communication network.
- o Creates and updates a "cell model" indicating the position of each mobile unit within its cell (coverage area).
- o Determines from the cell model and the cell coverage profile when communication with a particular mobile may be unsatisfactory, and buffers messages for that mobile unit until it is in an area of satisfactory communication. If satisfactory communication can not be achieved in a reasonable time (depending on message priority), generates an error message to the network manager.

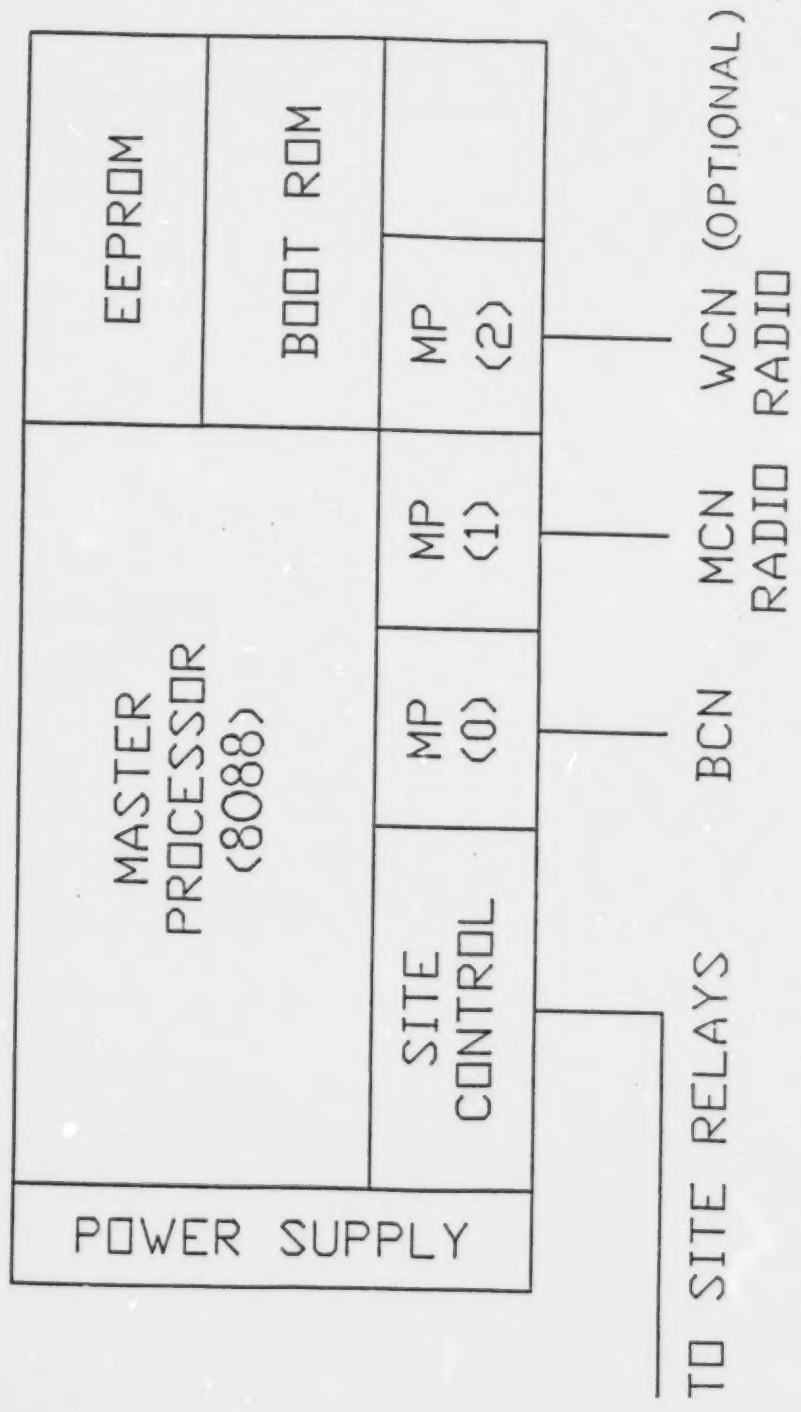


Figure 5 SITE CONTROL UNIT BLOCK DIAGRAM

- o Executes commands directed to it for the purpose of establishing and maintaining virtual paths to mobile units in its cell.
- o Determines when communication errors occur, gathers statistics on communication events, and reports "lost messages" to the NWM if message retry and rebuild procedures fail to be effective.
- o Recognizes priority of messages to and from mobile units and deals with them appropriately to minimize response time for higher-priority messages.
- o Performs routine background diagnostics on its portion of the communication network, and reports results to the NWM.

3.4.5. Signal Profile Mapping Function

For the signal profile mapping function, we originally intended to measure absolute signal strength by extracting a suitable voltage measurement from the train and site radios. Signal quality would have been measured by having the radios transmit a brief period of un-coded tone on the radio carrier at the end of certain transmissions, and making and storing a signal-to-noise-and-distortion (SINAD) ratio measurement on those transmissions. We found, however, that it was difficult to obtain consistent signal-level measurements, and that the addition of the SINAD tone periods took up an inordinate amount of channel time on the mobile channel. Therefore, we sought an alternative method of determining signal quality.

Since the real measure of signal quality for a data communication system is the error rate, or frequency of retrys required to pass a message successfully without error, NKG Systems wrote a set of software for use in determining signal quality measurement directly. In use, one terminal generates a series of messages which are sent out to another terminal at programmed intervals and in a pre-determined sequence. Each terminal and node keeps statistics on the number of messages transmitted, the number of retrys required before an acknowledgement of error-free reception is obtained, the number of CRC (cyclic redundancy check) errors detected in incoming messages, the location and speed of the mobile unit involved in the test, and the time of day for the test.

The terminal which receives a test message acknowledges the message when it is received correctly, then constructs a reply containing the received message but with the statistical data appended to it, and sends the reply to the originating terminal. When the originating terminal receives an error-free reply, it acknowledges the reply, compares it with the original message, and stores the statistics from the remote terminal along with those it produces locally. If an error-free reply is not received, or if the reply does not compare with the original messages, a "lost message" is declared and that event is stored with the statistics. Similarly, if the system declares a "link down" event (total loss of communication with a terminal) during the course of testing, that event is stored with the other statistics.

3.4.6. Signal Qualifying Function for Locomotives and Site Control Units

From the stored statistics, we can construct a signal-quality histogram related to location along the track. That histogram can be stored in each SCU and OBT, and can be used by the SCU's and the OBT's to determine in advance the likelihood of success in passing a message between them for any particular location of the affected train. Appendix F contains a set of six typical histograms, from data taken over a six-day period.

It may seem obvious, but it is important for each SCU and OBT to be using the same histogram for a portion of track. If one has data that there is a reasonable probability for success at a given location, and the other has data that there is not, and therefore will not respond, the result will be a declared communication failure which may not have been necessary. For that reason the histograms (or signal-quality profiles) are not updated dynamically, but only periodically when substantial new data are available and can be loaded into all units.

3.5. Vehicle Equipment, Hardware and Software

The vehicle equipment used for Phase II is essentially that developed in Phase I, except for the development in this phase of a Graphic Display Unit (GDU) to display not only text but also track graphics on-board the train.

3.5.1. Conflict and Management Processor

The central processor of the On-Board Train (OBT) equipment similar to an IBM PC/XT mother-board. It contains 640K of RAM (random-access memory) and an 8K EPROM (erasable programmable read-only memory), and has room for an additional 128K of ROM (read-only memory). The EPROM contains enough system memory to "boot" the OBT, while the remainder of the program can be down-loaded into RAM via the mobile communication network. For the test-bed system, to save loading time and to handle frequent program changes expeditiously, we have equipped the OBT with a floppy-disk drive to load the programs.

Figure 6 is a block diagram of the OBT central processor.

The central processor maintains all the data tables necessary to store authorities issued to the train and to all other trains, m.o.w. units and work gangs within the train's supplied limits, to store signal-quality profiles, and to store other operating data which is required during train operation. With those data available, potential conflicts can be detected and annunciated, and the engineman can be advised of track occupancy and other conditions which affect safe train movement.

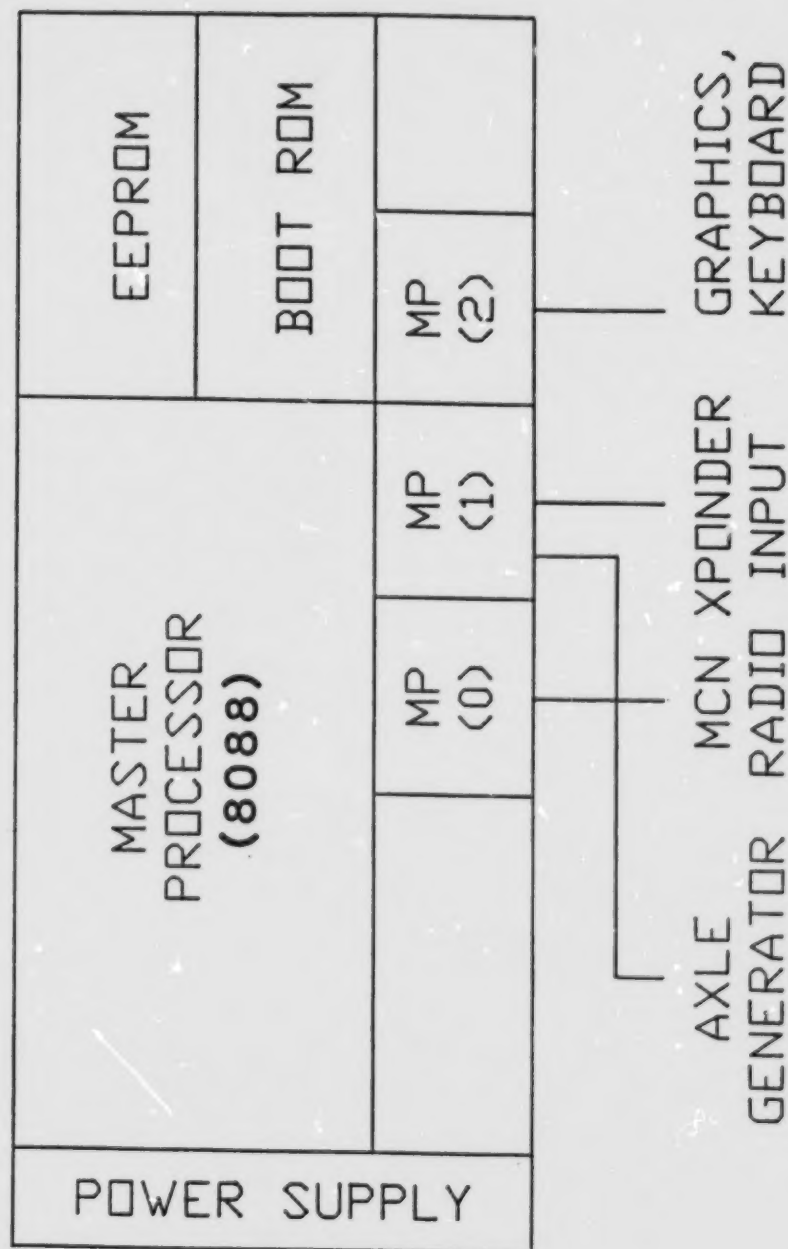


FIGURE 6. On Board Train Processor Block Diagram

3.5.2. Communications Processor

Mobile radio communications to and from the OBT are dealt with by a Communication Processor, the NKG type PC-104, equipped with a "piggy-back" NKG type PC-103 modem. The communication processor uses a Z80 CPU and dedicated RAM to process messages independently of the main OBT processor. Figure 7 is a block diagram of the Communications Processor.

The Communication Processor generates bid messages for channel access, and recognizes grant messages as either permission to transmit or prohibition against transmission, depending upon the circumstances. It identifies and processes the synchronizing word, address word, and data words to obtain synchronization and to perform error-checking on received messages, and strips the CRC bits from incoming code words. It encodes outgoing messages for transmission, adding the necessary CRC bits to each code word. It provides immediate acknowledgement of messages received without errors.

The Communication Processor includes a 16Kbyte buffer for received messages, and a 16Kbyte buffer for messages to be transmitted.

3.5.3. Central Interfaces Module

The functions of the "central interfaces module" contemplated in the Statement of Work are performed in fact by two additional Communication Processors equipped in the OBT. Each of these is an NKG type PC-104 similar to that used for mobile radio communications, but without the piggy-back modem.

Figure 8 is a block diagram of the complete OBT sub-system, showing how the three Communication Processors act as interfaces for the various devices connected to the central processor.

Each PC-104 provides two RS-232 serial interface ports. We use both ports of one of the PC-104's to provide interfaces for the interrogator controller (a separate external control package) and for the axle generator, and we use one port of the other PC-104 to provide the interface for the Graphic Display Unit (GDU).

All three of the PC-104 boards used in the OBT have the same hardware; they differ only in the software they use, and in whether or not a piggy-back modem is equipped. (The modem, when equipped, uses one of the two serial ports, leaving only the second port available for external devices.)

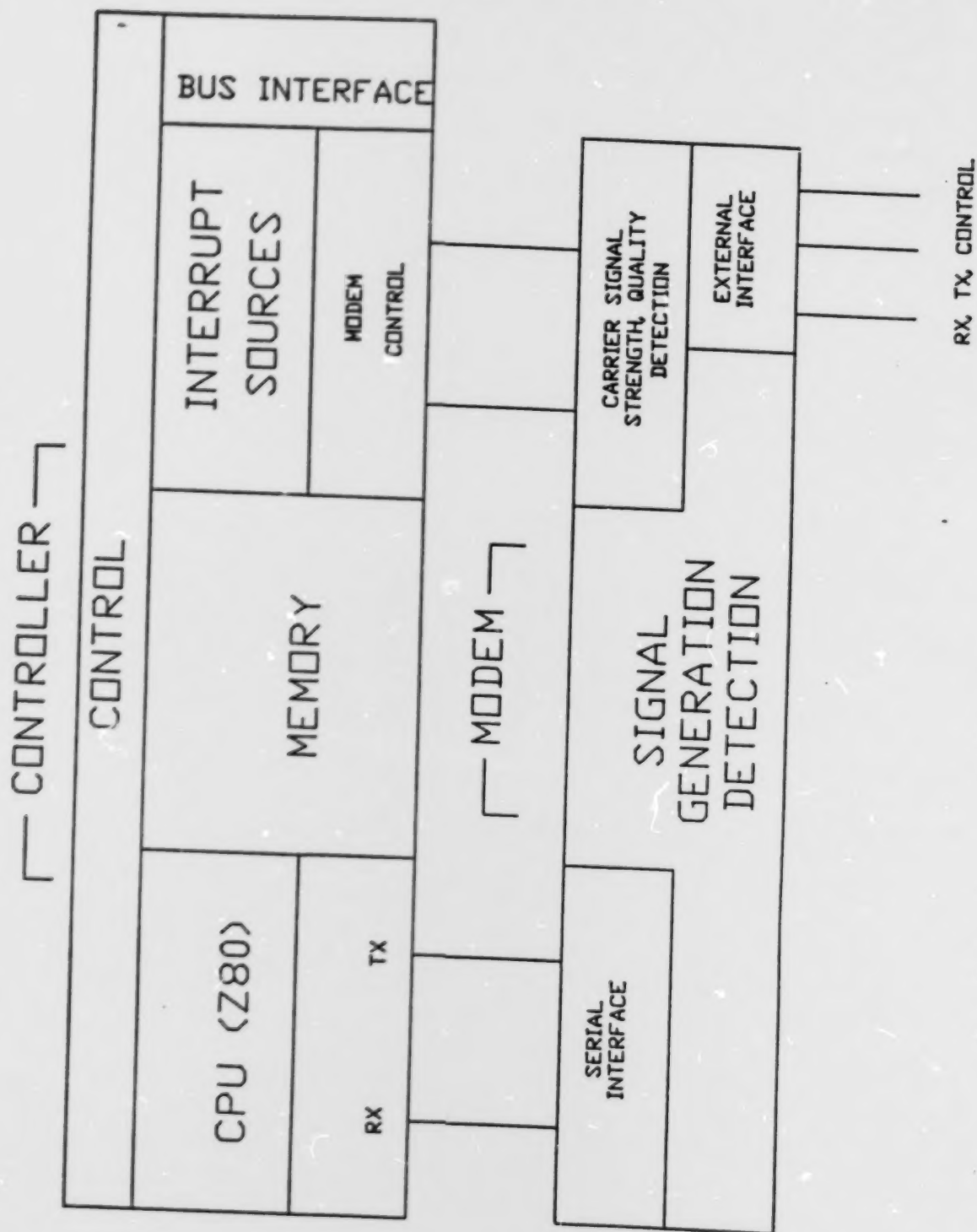


Figure 7 COMMUNICATION PROCESSOR BLOCK DIAGRAM

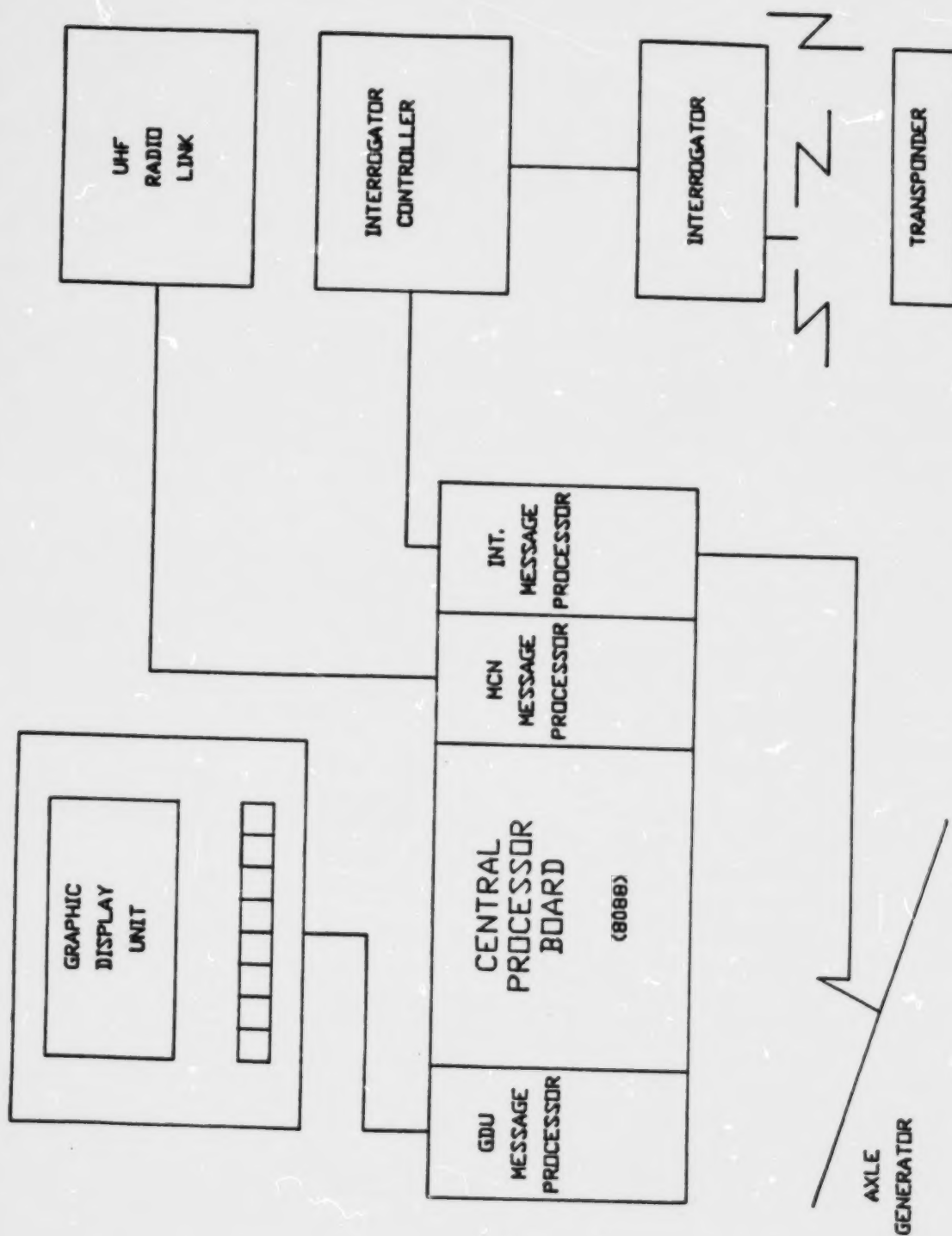


Figure 8 ON BOARD TRAIN SUB-SYSTEM

3.5.4. Graphics Display Unit

The Graphics Display Unit (GDU) consists of a high-resolution electro-luminescent monochrome display and an eight-key flexible-membrane keyboard, plus associated electronics, housed in a metal case. The GDU provides the interface with the engineman in the locomotive cab.

The GDU displays information to the engineman in several programmable "windows". Figure 9 is a diagram of the window layout used during field tests. The upper left corner window shows speed and location information, as "Pacing", "Current" and "Next", or "P", "C" and "N", values. Pacing is the desired value, Current is the measured value, and Next is the target which will take effect at the next control point.

Below the first window, on the left, is a window which has been used for communication monitoring during the tests. It shows the I.D. of the last two transponders crossed, the condition of the mobile communication link, the fact that an emergency message has been transmitted (if one has), and the type (catalogue mnemonic) of the most-recent control message received.

In the lower left corner a window shows the I.D. of the train, as assigned by the dispatcher. Data tables in the Host and in the OBT relate that train I.D. to the hardware I.D. of the OBT.

In the lower right corner a larger window displays any text messages received. Messages may contain up to eighty characters, and remain displayed until acted upon by the engineman, over-written by a new message, or scrolled off the display by the engineman. (Text scrolling by the engineman has been designed but has not been implemented in Phase II.)

The upper right corner is occupied by a window which uses about half of the total display area to present track graphics. Up to five control blocks can be displayed, on five levels of track (the main line and up to four sidings or additional trackage). The display shows the name of each block, marks block boundaries with short vertical lines, and shows switches as small solid squares.

Normally the track is displayed as a thin line. Track for which an authority has been issued is displayed as a thick line, and the I.D. of the train holding the authority is displayed immediately above the line. If the authority is "joint" (shared with another train or maintenance-of-way unit) the I.D. of the other train or unit also shows above the line. An arrowhead on the end of the I.D. shows the authorized direction of travel, with arrowheads on both ends if authority is bi-directional.

A polarized screen covers the face of the GDU to reduce glare.

The keyboard provides up to 14 functions. The "Emergency" and the "Shift" keys have only a single function. The other six keys have a primary function as labelled, and a secondary function (programmable) when pressed together with the Shift key.

The associated electronics interface unit of the GDU includes a Z8 micro-processor. The interface reads the coordinates of depressed keys and delivers serially-encoded signals to the display message processor in the OBT. Power for the GDU is obtained from the OBT via the modified RS-232 interface and connecting cable.

3.6. Conducting Shop Tests

Following production of the necessary communications hardware and software, we shop-tested all equipment to assure individual performance. The procedure involved connecting the unit under test to a simulator unit and establishing communication between the two, then generating test messages and observing the results both on the communication link and within the equipment.

The basic hardware of the each type of unit in the communication network is similar; therefore, we used what is essentially a site control unit for the simulator. NKG wrote special test software to permit us to generate every type of message used in the system, and to display the results in formats useful for test purposes.

While the communications equipment was under test in NKG's shop, BC Rail was testing the Host computer system in the dispatch office. These tests involved working through a set of nineteen typical operating scenarios, as described in section 3.3.1.

3.6.1. Network Manager/Cluster Controller

We began the shop tests of the Network Manager by physically inspecting the unit and measuring and recording critical voltages from the power supply and on the circuit boards. All were within specification.

To test the functions of the NWM (which for this system includes the functions of the Cluster Controller), we set up the simulator to function as a Site Controller. We then set up a four-wire communication link between the NWM and the simulator. We arranged to connect a protocol analyzer to the PC-104 message processors in the NWM and in the simulator, as needed.

Both the NWM and the simulator are equipped normally with a video display driver and CRT display, and we used those to observe the end results of the tests.

During the tests we generated messages, first from the NWM to the simulator and then from the simulator to the NWM, using all of the message types which each would generate in normal operation (including free-form text). We inserted various levels of attenuation in the communication circuit, and applied interfering noise as a swept-frequency tone on either side of the channel.

We observed the bit patterns of the messages and of the responses to the messages on the communication link with the protocol analyzer, and the decoded results on the CRT monitors. All messages were sent several times, and all operations were according to specification. Messages were received successfully with interfering tone level equal to and in some cases exceeding the level of the desired signal.

It is worth noting that the modem output levels from the NWM and from the simulator for this series of tests was -29 dBm (13 dB below the -16 dBm test-tone level for the input to the microwave multiplex).

3.6.2. Site Control Units

We tested the four Site Control Units in a similar manner to the NWM, beginning with a physical inspection and a check of operating voltages.

For the functional tests, we used the previously-tested NWM on the backbone communication side of each SCU, and the simulator on the mobile communication side. In this case, the simulator was set up as an OBT, and the NWM was operated in its maintenance mode.

We equipped the SCU under test with a video driver board and CRT monitor so that we could observe the results of messages as they were received by the SCU.

The communication link between the SCU and an OBT in normal operation would be a mobile radio channel, with "open squelch" (that is, with significant noise output from the radio receiver when no incoming signal is being received). To simplify the tests, we used two pairs of wire lines instead of the radio channel. The modem output levels to the radios are 0 dBm, considerably higher than for the microwave multiplex, and with no attenuation in the link, the received levels for the tests were also 0 dBm.

As before, we arranged to observe the bit stream for messages sent and for responses, on both the "backbone" channel and on the "mobile" channel, using the protocol analyzer. We generated messages of every type which would be used in normal operation, from the NWM to the SCU and to the simulator, from the simulator to the SCU and to the NWM, and from SCU to the simulator and to the NWM. We inserted attenuation in the communication channels, and applied interference as a swept-frequency tone on either side of the channels.

We observed the bit patterns of the messages and of the responses to the messages on the communication link with the protocol analyzer, and observed the decoded results on the CRT monitors. All messages were sent several times.

Between the NWM and the SCU's, all operations were according to specification, with results essentially identical to those from the NWM test. However, between the OBT simulator and the SCU's we observed an apparent anomaly — the results without attenuation or without the interfering tone were poor compared to those obtained with the interfering tone. We eventually traced the problem

to the fact that the communication modem receivers use AGC (automatic gain control).

With no interfering signal, the communication channel is quiet, and the AGC acts to increase the receiver gain to maximum. When the desired signal is turned on, at a 0 dBm level, the AGC requires a finite time to reduce the receiver gain to a reasonable level. In the meantime the received signal overloads the receiver, producing severe distortion and causing errors. When the interfering signal is present, the AGC acts continually to reduce the receiver gain so that when the desired signal appears, the receiver is not overloaded. Similarly, if the desired signal is significantly attenuated, it does not suddenly overload the modem receiver. With an actual radio channel in use, with open squelch, normal channel noise results in correct AGC action even without an interfering signal.

After taking account of AGC action, we obtained operation between the OBT simulator and the SCU's according to specification.

3.6.3. On-board Train Units

Having tested the NWM and the SCU's, we proceeded to test the OBT's, together with their associated GDU's and interrogator controllers, in a similar manner.

Initially, we set up the simulator as a combined SCU/NWM, connected to the OBT's with wire line rather than a radio channel, as for the SCU tests. We equipped the OBT under test with a video driver and CRT monitor to allow us to observe results directly as well as on the GDU display. We inserted attenuation and applied interference as before. We generated all of the messages required to be transmitted and received by an OBT.

We observed the bit patterns of the messages and of the responses to the messages on the communication link with the protocol analyzer, and observed the decoded results on the CRT monitors. All messages were sent several times. The results were according to specifications, after taking account of AGC action as described in Section 3.6.2.

During the process of testing the OBT's, we also tested the interrogator controllers and the GDU displays. We tested the interrogator controllers by waving test transponders past the interrogators within the specified range of distance and speeds, and observed the results. All were according to specification.

We tested the GDU's by observing the results of other tests on the display, and by using the keyboard to respond to incoming messages, to scroll the track graphics display, and to send the emergency check message. We found that the GDU is rather more sensitive to power supply voltage than is desirable, and has a tendency to "hang up" or "freeze" on minor dips of the supply voltage and on experiencing noise on the power lines. NKG modified the software to provide a "heart beat" cursor in one corner of the display, so that we can determine whether the display is responding, and provided a reset circuit so

that a frozen display can be reset without having to reset the OBT. We decided that the GDU's as modified were sufficiently operational to use for the test bed, although improvements will be required before they will be acceptable for regular service.

3.6.4 System Integration

Having tested all units individually, we then arranged to interconnect the NWM, an SCU and two OBT's as a system, for test.

We generated a variety of messages from various terminals and passed them successfully through the network. However, we did not have sufficient equipment to simulate the communication channel conditions properly, so the value of this integrated sub-system test is doubtful.

When we were satisfied that we had done all that we could to test the communication and train sub-system equipment, we moved the NWM and one of the SCU's to the North Vancouver communication site room, where it would be permanently installed. We connected the NWM to the Host computer (which had been installed previously, and tested), and generated messages between the Host and the NWM. No problems were apparent at that time.

3.6.5. Preparation of Reference Manuals

We have prepared reference manuals for the Network Manager, the Site Control Units and the On-board Train Units.

3.6.6. Preparation of Operator Manuals

We have prepared operator manuals for the Train Operator (OBT equipment) and for the Dispatch Operator (Host equipment). Those manuals are available as documents MAN 86-101BCR and MAN 86-102BCR, respectively.

3.7. Conducting Field (On-site) Tests, Squamish Subdivision

The BC Rail track from North Vancouver to Squamish (the south end of the Squamish subdivision) forms the south portion of the Train Control Test Bed. Specifically, it includes the main line and all sidings and auxiliary trackage between mile 2.5 (within the North Vancouver Yard) and mile 42.0 (the north end of the Squamish Yard).

We established three UHF radio sites to provide radio coverage over the south test bed: the Head Office building, near mile 0; the Watts Point microwave repeater site, near mile 33; and the Squamish microwave repeater site, near mile 38. The North Vancouver site is intended to provide coverage from mile 2.5 to the south end of the tunnel at mile 10.5. The Watts Point site is intended to provide coverage from the north end of the tunnel at mile 11.5 to approximately mile 35. The Squamish site is intended to provide coverage from mile 35 north. There is considerable overlap in these coverage areas, but that is not a problem because we use two duplex frequency pairs; one pair at North Vancouver and at Squamish, the other pair at Watts Point.

Each site is equipped with an SCU, which interfaces with a voice-grade multiplex channel on the microwave system. The Squamish and Watts Points SCU's are bridged onto the same channel as it passes through their sites. The Tacheeda site uses a separate multiplex channel directly to North Vancouver. The two multiplex channels, the North Vancouver SCU, and the Network Manager are bridged together where they appear in the North Vancouver microwave terminal room. The channel is four-wire throughout. Modem transmit and receive levels are set at -13 dBmO (13 dB below test-tone level for the multiplex).

The UHF radio at each site provides approximately 30 watts to the duplexer, and uses a Sinclair 307 Yagi antenna to provide approximately 10 dB of forward gain and to provide some directivity to reduce multipath signal levels. The North Vancouver antenna is aimed generally westward along the track to Horseshoe Bay, the Watts Point antenna is aimed generally southward toward Horseshoe Bay, and the Squamish antenna is aimed generally north-north-west over mile 42. (The track between mile 32 and mile 38 is served from the back and side of the antennas — however, the path lengths are relatively short.)

The train radios provide 30 watts output as well, but use Sinclair 321A Excaliber antennas, which have nominal unity gain. The pickup truck uses a 1/4-wave whip antenna, also unity gain.

The modem tone levels to and from the radios are nominally 0 dBm, with the radios set to provide approximately 3 kHz deviation for that level. The radio pre-emphasis/de-emphasis circuits have been by-passed to provide "flat" audio-frequency response and reduce phase-shift through the radios.

3.7.1. Test Procedure

We organized the field tests in stages: first, interworking of the network manager and the site control units; then interworking of a train with the North Vancouver site control unit; then the complete communications subsystem (network manager, site control units, and train). The final stage connected the host to the network manager to bring the whole system together.

The first stages went fairly smoothly, except for several initial hardware failures which highlighted the differences between the laboratory and field operating environments. We encountered difficulty, however, when we attempted to bring the host onto the system.

In the meantime we disconnected the host and continued with field testing using the network manager in its maintenance mode.

In performing the tests, our goal was to demonstrate an acceptably high rate of success in passing messages to and from trains, and to demonstrate that all message errors are detected and result in message rejection (no messages accepted with undetected errors).

3.7.2. SCU to NWM Communication

The NWM includes software which enables us to establish communication (set up a virtual path) to any node or terminal of the communication network, and to monitor traffic on the network. We used that software to exercise the backbone network and the equipment on it (the NWM and three SCU's) for several days after installing all equipment. Generally, the results were good, as expected. However, we found some minor software problems which related to having more than one SCU connected to the backbone and all able to hear each other -- a situation we had not tested in the shop tests. These problems were identified and corrected quickly and without difficulty.

Under some conditions we were able to make the Watts Point SCU "hang up" or refuse to respond to commands. When this occurred it was necessary to reset the SCU, so we added a circuit at the Watts Point site to permit us to do that via the microwave supervisory control system when necessary. Recently, we were able to investigate the problem properly, and found that the SCU motherboard had an intermittent connection. Replacing the motherboard has cured the problem.

3.7.3. Locomotive to SCU Communication

When we were satisfied with the backbone communication subsystem, we began testing between the North Vancouver site and the V-10. For these tests, the V-10 operated within the North Vancouver Yard and along the first few blocks of track south of Horseshoe Bay.

3.7.4. NWM to Host Communication

We had intended to use the Ethernet data communication protocol for communication between the Host computer and the NWM, and had purchased hardware for that purpose from DEC. However, DEC's Ethernet software only provided support for 10-Mbps communications, whereas readily-available "Ethernet-compatible" hardware for the NWM could only support 1-Mbps communication. We would have used DEC DVP-11 synchronous-communication hardware, but found that DEC had no software available to support it. Thus, we were reduced to using the standard DEC Vax serial asynchronous communication ports for network communication.

Since we could not use Ethernet, for the test-bed system we have used the NKG protocol at 1200 bit/second (without the bid/grant contention control, since there are only two terminals on the link). The data communication rate is low, but with only three SCU's and with little traffic from the test trains, it does not represent a restriction for the test-bed system.

At first we used only a single port of the MicroVax. Communication was unreliable, with frequent Host crashes whenever the network communications function was stressed with large amounts of data traffic. We eventually determined that the MicroVax port was unable to handle true duplex traffic (simultaneous transmission and reception of data), although it is referred to in the DEC literature as a duplex port. To overcome the problem, we had to use two ports of the MicroVax; one for data transmission and one for data reception. Both MicroVax ports communicate with a single port of the NWM.

3.7.5. System Communication excluding the Host

During the period when we were experiencing difficulty with the Host-NWM communication, we carried on with the tests by using the NWM in its maintenance mode. This mode permits us to generate all messages required by the system, and to receive and recognize messages incoming to the NWM from SCU's and OBT's. We ran the V-10, and at times the V-10 and the pickup truck, over the southern test-bed for several weeks, sometimes running the V-10 back and forth between North Vancouver and Squamish as many as three times in a day.

When running "echo" tests, we generated and recorded data from messages at periods as short as 5 seconds between messages, but more usually 20 seconds between messages. We averaged about 150 messages per hour while the system was running, for a total in excess of 15,000 messages. We did not record the results of all tests, however, since we were experiencing hardware failures of both the OBT equipment and of one of the SCU's.

3.7.6. Total System Communication

After arranging to use two ports of the Host for communication with the NWM, we have had no further difficulty with total system communication. The NKG protocol is used throughout the system, at 1200 bit/second. Each SCU controls contention by OBT's on its mobile communication channel, and the NWM controls contention by the SCU's on the backbone communication channel.

3.8. Conducting Field (On-site) Tests, Electrified Territory

We have conducted field tests on the electrified territory of the northern test bed on May 19 through 21, 1987. We were unable to conduct the tests earlier because the V-10 track inspection vehicle, which is our main test train, does not run well in snow and ice. By the time we were ready to test in the north, winter weather had settled in.

3.8.1. Test Procedure

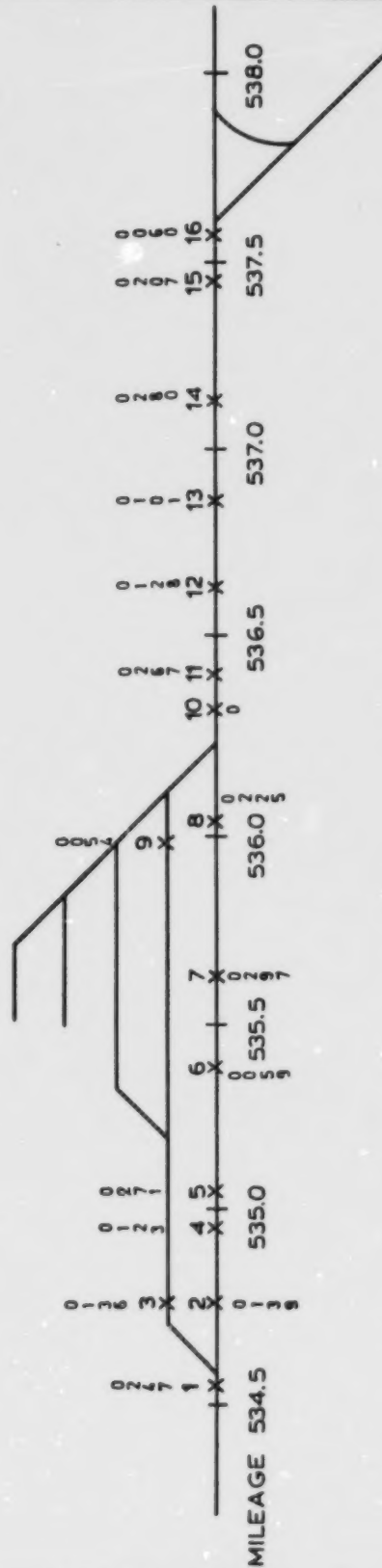
Upon arrival at the test site at noon on the first day, we deployed transponders between Tacheeda and Wakely as shown in Figure 10. We then made the equivalent of two return trips over the test bed. Two electric engines were idling on a stub track during these trips, but there were no active electric engines on the test bed. We found that four of the original transponders were defective. We replaced those, and replaced a fifth transponder to avoid possible ambiguity in identifying the transponder pair:

- #0205 defective, removed and replaced with #0139
- #0207 defective, removed and replaced with #0297
- #0226 defective, removed and replaced with #0128
- #0234 defective, removed and replaced with #0101
- #0236 removed and replaced with #0168

On the following day we made a total of 16 return trips over the test bed, while communicating with the dispatch centre over the data communication system. There was only one electric train operating during this series of tests, on trip #10. We lost the "heart beat" on the cab display during trip #11, which required us to reset the OBT and the interrogator (not related to electric operation of trip #10). At the end of the day we made arrangements through the dispatch office to deadhead a crew to the site to operate an electric engine during the final day of tests.

On the third morning the electric train crew took a pair of engines onto a siding paralleling the test bed. They ran the engines up and down the siding, with one engine providing traction and the other engine in the dynamic-braking mode to provide a load and draw significant current from the catenary. On this day we made the equivalent of eight return trips over the test bed. We made some of the trips running alongside the electric engines, and some running in the opposite direction to the electrics. Test results were similar to those of the previous days without electric engines operating. The cab display screen failed on the first trip and required us to reset the OBT, but there were no other significant problems.

C-

WAKELYTACHEEDA

LEGEND: X = TRANSPONDER

FIGURE 5-1 TRANSPONDER DEPLOYMENT IN ELECTRIFIED TERRITORY

REVISIONS

COMMUNICATIONS

DR. AH	PLNR. E.S.
CH.	CH.
SC.	APPD.
DATE NOVEMBER 27, 1985	

TRANSPONDER DEPLOYMENT IN ELECTRIFIED TERRITORY


**BRITISH
COLUMBIA
RAILWAY**

 DWG
NO.

C-

REVISED 07-05-25

DIST-

3.8.2. Locomotive to SCU Communication

The locomotive to SCU communications performance during these tests on electrified territory was essentially identical to that obtained during the tests on non-electrified territory. We could see no evidence of degradation of performance during any of the tests on electrified territory.

3.8.3. Total System Communication

Total system communication during the tests on electrified territory was essentially identical to that obtained during tests on non-electrified territory. We could see no evidence of degradation of performance during any of the tests on electrified territory.

A significant observation is that the transponder/interrogator systems work well in electrified territory. During the test trips on the first day, four bad-order transponders were identified and subsequently replaced. After that, every transponder was correctly identified during every trip of the V-10.

3.9. Corrective and Preventive Maintenance

BC Rail has performed, or arranged for the performance of, corrective and preventative maintenance of the sub-systems and the system, in accordance with the development contract. NKG, as subcontractor to BC Rail, has been responsible for corrective and preventative maintenance on the communication and train subsystems, and BC Rail has retained responsibility for the Host computers.

During the field tests we were required to shut down the SCU at Watts Point for several days in response to complaints about interference to signals from a low-power local TV repeater. NKG Systems Ltd. took the necessary steps to reduce spurious radiation from the SCU (involving by-passing of all external leads where they leave the SCU enclosure, plus ferrite beads on all the leads immediately ahead of the bypassing), and we were able to resume operation without further complaints.

3.10. Hardware Production Drawings, Software Manuals and Source Listings

Hardware production drawings, software manuals and source listings for all software have been produced and are available for inspection. Because of the sheer volume of documentation, distribution of this documentation has been limited; however, the contractual obligation has been met.

3.11. Slide Presentation

We have prepared a slide presentation, describing the work done in this Phase II of the BC Rail Train Control Project, and have presented it to groups within BC Rail and to others, including TDC. A copy of the slides and of the audio cassette, with slide-controller key track, has been delivered to TDC in accordance with the terms of the development contract.

4. OBSERVATIONS

When LIC was under test, there were frequent instances of "missed transponders" -- occasions when transponder crossings occurred but were not reported to the Host computers. At the time, we suspected that the communication system was at fault, rather than the interrogator/transponder system. We have experienced no difficulty identifying and reporting transponders during the Phase II tests.

The radio-channel error rate rises noticeably when a train is in motion compared to when the train is stationary, as expected. It is apparent that longer messages are errored more often than are shorter messages -- in our "Echo" tests the echo message from the OBT is longer (three words) than the original message from the SCU (one word), and the retry rate is higher for the OBT.

We carefully tagged every message sent in the "Echo" test, and tagged and compared the response with the original, bit-for-bit. We sent approximately 15,000 echo test messages, each involving two acknowledged message transmissions. Not one was accepted with an undetected error. If the average retry rate was 1 (i.e., every acknowledged transmission had to be retried once for success) this represents a total of 60,000 message transmissions with no undetected errors.

The test-bed system functions very well with the NKG protocol used on all communication links, at 1200 bps, with only two or three trains in the subdivision. However, the system is noticeably slow when there is much communication traffic (e.g., when we are running "echo" tests on a 20-second cycle while dispatching trains from the Host). At this time we have not identified the source of the delay, although it appears to relate to the Host/NWM data link.

We performed the majority of the communication tests using the network manager in the maintenance mode. We also ran several tests from the dispatcher console, and the communication results were identical to those obtained from the network manager alone, provided that the data tables maintained in the two machines were consistent with one another.

The manual dispatching mode which we developed as a "fall-back" mode for the Level 30 system can function quite well as a Level 10 system, although the fact that the system will not allow authorities to be issued beyond "the point of conflict" introduces a substantial work load for the dispatcher. (He has to issue several unrestricted authorities, in pieces, instead of a single authority, with restrictions, as he does now.) Certainly, we have gained the experience necessary to specify a good Level 10 system which will assuredly be upwardly-compatible with a Level 30 system.

The communications network hardware functioned well enough to demonstrate the communications capability, and to highlight the value of the high degree of commonality of components. We did experience a significant number of hardware failures, and found the equipment rather intolerant of low power supply voltage. The communication network software proved to be useful and readily adaptable to changing requirements.

5. CONCLUSIONS

The interrogator/transponder train-location method is effective and reliable.

The development and use of a "message catalogue" rather than free-form messages has been an essential element of our success in data communication with trains. The short messages obtained in that way have allowed us to use a relatively-simple and reliable error-detecting code, without forward error correction.

The communication protocol as implemented is not as described in the protocol documentation (a 16-bit CRC is used, instead of a 15-bit CRC plus a parity bit; and the leading-bit distinction between address words and data words has not been used). However, we have done sufficient transmission testing to demonstrate that the code format used is capable of detecting and rejecting errored transmissions with a very low probability of failure. (No failures occurred during our tests.) The predicted worst-case probability when properly implemented is about $2(10^{-6})$, and could be much smaller¹. However, at the rate of 750 tests (3000 messages) per day, we would have to continue the tests for several years to prove that capability.

Communication between the MicroVax computers and the Network Manager must be improved significantly if more than a few trains are to be handled by the system. Similarly, communication on the backbone system should be upgraded to X.25 and operated at not less than 4800 bps (probably 9600 bps), if more than a very few Site Controllers are on the system.

¹ "Preferred Data Transmission System for Land Mobile Radio Using a Binary Format", European Engineering Association, Leicester House, 8 Leicester Street, London WC2H 7BN, 7 June 1982.

The principle of using common basic hardware modules in the communication network is desirable from a test and maintenance viewpoint. The communication hardware as it stands is not sufficiently reliable for operational service, and is not sufficiently tolerant of low supply voltage. The communication network software has performed well.

The method of using "Echo" test data to develop signal-quality histograms is more effective than attempting to measure signal strength and SINAD ratios as a continuing process.

The functions of the Host computer system and of the communications network are readily separable and permit a clean and well-defined interface between them. Thus, it is reasonable and practical to develop these two sub-systems somewhat independently; with confidence that they can be interconnected without difficulty, provided that the interface specification (including the content and format of the messages to be passed between them) is carefully specified and the specification is adhered to.

6. RECOMMENDATIONS

These recommendations deal only with suggestions for improvement or future work, and not with adoption of equipment or techniques whose value is obvious from results of this or previous work.

6.1. Upgrade the Protocol Implementation

We recommend that the implementation of the NKG protocol be upgraded to conform to the EEA code format with respect to CRC and parity bits, and with respect to leading-bit differentiation of address and data words.

The present structure of the Bid and Grant words in the NKG protocol is probably less than optimum and should be reviewed and made optimum.

6.2 Upgrade the Host/NWM Communication Link

We recommend that a suitable Ethernet implementation at 1 Mbps for Host/NWM communication be obtained; and if such an implementation cannot be obtained at reasonable cost, the use of DEC equipment for the Host be reviewed.

6.3 Upgrade the Backbone Communication Link

We recommend that an X.25 protocol be implemented for the backbone communication link, at 9600 bps if possible. Further study of the traffic-handling capability of the backbone communication network is desirable, as well, to ensure that it will not become a bottle-neck with several trains active in the system.

6.4 Upgrade the Communication and Train Sub-systems Hardware

We recommend that the hardware for the communication sub-system and for the train sub-system be upgraded and re-packaged to make it more compatible with the intended operating environment. Particular attention needs to be paid to:

- o Reduction of electromagnetic and electrostatic interference, both to the equipment and by the equipment.
- o Greater tolerance to a wide range of supply input voltages, and to transients on the power supply.
- o Increased mechanical strength and resistance to vibration and acceleration.
- o Physical size and form factor, in relation to available mounting space and arrangements in engines.

6.5 Improve the Graphic Display Unit and Engineman's Keyboard

We recommend that further work be done on the graphic display unit, to:

- o Improve the brightness and contrast ratio of the display.
- o Provide two-way communication with the display, to obtain positive confirmation that the display is functioning and is displaying information correctly.
- o Provide greater tolerance to low power-supply voltage input.

We recommend that consideration be given to separating the keyboard from the display, to allow greater flexibility in the placement of the two units; and to increasing the number of keys on the keyboard by at least adding a numerical keypad, so that the engineman has some increased capability for originating messages to the dispatcher.

APPENDIX A

Conclusions from Phase I, TP 7269E

7. CONCLUSIONS

This section contains the conclusions which can be made for the present LIC system development based on the experience gained and the information presented in this report:

7.1 Communications

The following conclusions can be made about the communications system:

- the communications were redeveloped, which included the Network Manager, Cluster Controller, Site Processor, RPU and Modem.
- the message format was changed.
- modem speed was increased to 1200 b.p.s.
- communications were switched from asynchronous to synchronous.

7.2 Host Computer

The following conclusions can be made about the Host computer:

- the hardware is unable to efficiently run the software due to execution speed, and internal and external memory size.
- the PDP 11/44 16 bit processor does not perform the required processing in an efficient time frame due to the fact that 15 year old technology is being implemented.
- the Ultrix-11 operating system lacks the common storage capability that is required to allow efficient implementation of the Host software.
- the 'C' language that was chosen for system development has proven to be effective in implementing the software.

7.3 Locomotive Equipment

The following conclusions can be made about the locomotive equipment:

- the locomotive equipment was redeveloped, which included the OBT processor, communications processor, and the GDU.
- the GDT was a mock up provided on a microcomputer.
- equipment was not installed on the track inspection car (V-10) due to the problem with the Host computer.

7.4 Tumbler Ridge Subdivision

The following conclusions can be made about the Tumbler Ridge subdivision:

- transponders and modems were installed.
- the RPU was not moved from the Squamish subdivision.
- the microwave channel was provided between Tumbler Ridge and the North Vancouver dispatching centre.
- tests were not run because of problems with the Host computer, therefore there were no test results available for comparisons to be made.

8. RECOMMENDATIONS

On the basis of the information presented in the preceding Sections and the conclusions drawn from it, the following recommendations are made:

- purchase new Host computer (Micro Vax II).
- port software to new Host computer.
- evaluate possibility of transporting the Dispatcher's Interface from the PRO 350 to the new Host to achieve better compatibility and portability.
- extensively test communications system in mobile environment and prove system meets EEA standard for mobile data communications.
- display and handle non-equipped trains.
- display OBT graphics on a practical display unit.
- perform indepth traffic analysis of BCN and mobile communications network.
- enhance communications software to include analysis of communications statistics and real-time graphing of results.
- enhance OBT tracking to include all possible failure modes and compensations to dead reckoning.
- demonstrate end-of-train unit interface.
- demonstrate inclusion of wayside processors.
- demonstrate system with tracking and control.

APPENDIX B

Photographs of CRT Displays
Dispatch Centre



DISPATCHER'S CONSOLE

COMMUNICATION STATUS

NO. UNIT	COMMAND TYPE	MESSAGE TYPE	ERROR
-----------------	-------------------------	-------------------------	--------------

(PAGE 1

SYSTEM INFORMATION:

VIRTUAL PATH TO:

NO VIRTUAL PATH TO:

DISPATCHER COMMANDS
ISSUE MENU

NAME: X710M____ DIR: [n] [s] [bi] N_ ISSUE TYPE: [encl] [jnt] E____

ISS BLK FROM: MAY____ TRACK: 0_ ISS BLK TO: SPORT____ TRACK: 0_

EXECUTE [y] [n] Y_

EC RAIL

BLOCK CLEARANCE NO. 2

TYPE[MON][TRAIN]: T----

ISSUED TO: CONDUCTOR SMITH-----

ENGINEER SMITH-----

AFTER 11:11 THIS IS YOUR EXCLUSIVE AUTHORITY TO RUN X710N
NORTH BOUND FROM NBAY TRACK 0 TO SPORT TRACK 0

SPACE BAR-UNDERLINES WORD

APPENDIX C

Operating Scenarios for
Train Control system Tests

MANUAL TEST PROCEDURE

SUBJECT: 6.1 CREATE ONE TRAIN OVER WHOLE SUBDIVISION

SCENARIO: CREATE TRAIN M023 AT NORTH VANCOUVER ETD 22:00 ENG 701 EOT 1854 DESTINATION RSQUAM

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1	Enter 1	Create menu prompt "Menu="	M 11	M 11	This function allows the
2	Enter M023	prompts Train or ROW	"	"	host to create data space
3	Enter 1	prompts to ETO	"	"	for this train and down.
4	Enter 2200	prompts to B1, M, S, B1	"	"	loads information to
5	Enter M	prompts Speed, P1 or ADC	"	"	manual operation software
6	Enter 1	prompts Engine	"	"	advising that it may
7	Enter 723	prompts EOT	"	"	receive information on
8	Enter 1854	prompts Block from	"	"	this train in the future.
9	Enter M023	prompts Track from	"	"	
10	Enter 0	prompts Block to	"	"	
11	Enter 0	prompts Track to	"	"	
12	Enter 0	prompts Orig. Block	"	"	
13	Enter M023	prompts Origin Track	"	"	
14	Enter 0	prompts Execute M, Sys. or Mo	"	"	
15	Enter M				

To see a list of created trains in sys enter 5 in main command menu show trains and issued track authority.

MANUAL TEST PROCEDURE

SUBJECT:

6.2 CREATE ONE TRAIN OVER PART OF A SUBDIVISION

SCENARIO:

CREATE NO3 AT NORTH VANCOUVER LTD 10:00 ENGINE 702 EOT 1855 - DESTINATION STNR

DISPATCHER INPUT	CONRAD MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1 Enter 1	Create menu prompt "Menu"			
2 Enter NO3	Prompt Train or ROW			
3 Enter 1	Prompt to ETO			
4 Enter 10:00	Prompt Dir - M, S, B1			
5 Enter M	Prompt Speed - FRT, ROC			
6 Enter F	Prompt Engine			
7 Enter 702	Prompt EOT			
8 Enter 1855	Prompt Black from			
9 Enter NVAN	Prompt Black from			
10 Enter O	Prompt Black to			
11 Enter STNR	Prompt Track to			
12 Enter 1	Prompt Original			
13 Enter NVAN	Prompt Original Track			
14 Enter O	Prompt Execute M, Sys, or No			
15 Enter M				
				Same as 6.1

MANUAL TEST PROCEDURE

SUBJECT: 6.3 CREATE SECOND TRAIN BEFORE DEPARTURE OF FIRST TRAIN

SCENARIO: CREATE 1703M AT NORTH VANCOUVER ETD 10:20 (BLOCK NO3) EOT 1856 DESTINATION MSQUAN

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1	Enter I	Create Menu Prompt Name			
2	Enter 1703M	Prompt Train or MOV			
3	Enter I	Prompt ETD			
4	Enter 1020	Prompt ETD			
5	Enter M	Prompt B18-M.S.81			
6	Enter M	Prompt Speed-ft or RDC			
7	Enter 703	Prompt Engine			
8	Enter 703	Prompt EOT			
9	Enter 1856	Prompt Block from			
10	Enter 0	Prompt Block from			
11	Enter MSQUAN	Prompt Block to			
12	Enter 0	Prompt Block to			
13	Enter 0	Prompt Orig Block			
14	Enter 0	Prompt Origin Track			
15	Enter M	Prompt Execute M or Sys			

See as 6.1

MANUAL TEST PROCEDURE

Page 1

SUBJECT:

0-4 ISSUE EXCLUSIVE AUTHORITY ONLY TO ONE TRAIN

SCENARIO:

ISSUE AUTHORITY FOR M03 TO PROCEED NORTH VANCOUVER TO SEQUAN (SEQUAN)

DISPATCHER INPUT	CONRAD MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
---------------------	------------------------	----------------------------	---------------------------	----------

1 Enter 2
2 Enter M03
3 Enter M
4 Enter C
5 Enter EVAN
6 Enter O
7 Enter SEQUAN
8 Enter O
9 Enter V

Issue Menu
Prompt Name
Prompt Dir: N, S, B
Prompt loc: Type-Excel, JMI
Prompt loc: Block from
Prompt Block from
Prompt Track to
Prompt Execute V or M

10 Enter 1
11 Enter Smith
12 Enter Smith
13 Enter 10:00
14 Transm. verbally
15 4 under line by using space bar
16 Enter Return

Block auth. prompt
M0M or Train
Prompt Conductor
Prompt Engineer
Prompt Time
Prompt Underline
Prompt Return
Prompt Return

Double white over requested limits & ID & dir.
arrow over each block.

Double yellow over limits & ID & dir. arrow
over each block.

Note:

M03 new in first
Block of auth until
Block entry issued
when O/S by eng.

17 Enter p11
18 Enter M03
19 Enter SASET
20 Enter O
21 Enter M

Status Change
Prompt Name
Prompt Block Name
Prompt Track Type
Prompt Dir.
Prompt Block Entry, Clear

MANUAL TEST PROCEDURE

Page 2
SUBJECT:

6.4. ISSUE EXCLUSIVE AUTHORITY ONLY TO ONE TRAIN

SCENARIO: ADVANCE TRAIN BY BLOCK ENTRY TO SSQUAM - NO3

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
22 Enter E		Prompt Return for Current Time		
23 Enter 1110				Train positional arrow appears at start of SASET block.
24 Transmit Time				
25 Enter Pfl				
26 Enter NO3		Prompt Return		
27 Enter MBAY		Status Change		
28 Enter 0		Prompt Name		
29 Enter M		Prompt Block Name		
30 Enter C		Prompt Block Type		
31 Enter 1115		Prompt Dir.		
32 Enter Return		Prompt Block Entry Clear		
33 Transmit Time		Prompt Return for Current time		
34 Enter Return		Prompt Return		
				MBAY to MBAY Clear & NO3 authority remain SASET to SSQUAM

MANUAL TEST PROCEDURE

SUBJECT: 6.5 ISSUE EXCLUSIVE AUTHORITY ONLY TO SECOND TRAIN WITH PRECEDING TRAIN IN BLOCK
 SCENARIO: ISSUE EXCLUSIVE FOR X703M FROM HVAW TO MSQUAN

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
Repeat 1 through 16 - 6.4				
1 Enter 2	Issue Menu			
2 Enter X703M	Prompt Name			
3 Enter M	Prompt Dir M, S, B1			
4 Enter E	Prompt Iss Type-Excel, JMI			
5 Enter HVAW	Prompt Iss Block From			
6 Enter O	Prompt Track From			
7 Enter MSQUAN	Prompt Block To			
8 Enter O	Prompt Track To			
9 Enter Y	Prompt Execute Y or N			
Return 6.4, complete 17 through 34				
Manual interface will now prompt 86A				
11 Enter 1	Prompt Type ROW or Train			No response
12 Enter Smith	Prompt Conductor			No response
13 Enter Smith	Prompt Engineer			Double white HVAW-MSAY
14 Enter 1020	Prompt Time			
15 Enter Space Bar	Prompt Underline			
16 Enter Return	Prompt RTM for Current Time			
17 Enter Transmit Time				
18 Enter Return				Double yellow to block last cleared by the preceding train.
19 Pf 1	Status Change			
20 Enter X703M	Prompt Train Name			
21 Enter MSAY	Prompt Block Name			
22 Enter O	Prompt Track Type			
23 Enter M	Prompt Dir			
24 Enter E	Prompt Block Entry or Clear			
25 Enter 1111	Prompt Time			x703M arrow ID appears beginning of MSAY Block
26 Pf 1				Repeat of 18 through 24 above except use of clear instead of entry for MSAY

Information on create
and issue in 85 main
Menu - Train List

MANUAL TEST PROCEDURE

SUBJECT: 6.6 REVISE ONE TRAIN AUTHORITY

SCENARIO: REVISE FOR X703 NORTH TO SET OUT ONE CAR AT MBAY (TRAIN IN MBAY BLOCK)

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
---------------------	-------------------------	----------------------------	---------------------------	----------

Create and issue X703M MBAY to MSQUAM
Enter X703M in MBAY

- 1 Enter 3
- 2 Enter X703M
- 3 Enter 1
- 4 Use up arrow to enter fields to change
Dir - 81
Loc Block from MBAY
Track - A
Loc Block to MBAY
Use "Go" key after having entered fields to erase before entering new information.
Enter Y.

Note: This function at present cannot be accomplished. Can be overcome by issuing a dummy train over limits in jct authority such as: function can be performed by creating an issuance of JAT authority with himself as ENG. 710, MBAY and MBAY 710 being his second unit. This would work but not acceptable in an operational phase.

X703M in white as bi-directional in blocks in MBAY and MBAY.

New authority displayed
Requests underline
Prompt engineer's response
Grant or Decline
Prompt Return
Prompt Return

Blocks MBAY and MBAY double yellow white 10's in each block for X703M shown as bi-directional.

Transmit message
Underline as repeated
Enter Grant
Transmit Current Time
Enter Return

MANUAL TEST PROCEDURE

SUBJECT: 6.7 CREATE TRAIN TO LEAVE ON ARRIVAL OF TWO OTHER TRAINS
 SCENARIO: CREATE M016 AT STATE 1 SUM TO EVAN ARRIVAL M03 AND #703M

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1 Do scenario	4.2			
2 Repeat scenario	4.3			
3 Repeat scenario	4.4			
4 Repeat scenario	4.5			
5 Enter 1	Item 1 thru 9			
6 Enter M016	Create Menu prompts Name			
7 Enter 1	Prompts Train or ROW			
8 Enter 1130	Prompts to ETD			
9 Enter 5	Prompts to DIM M.S. #1			
10 Enter F	Prompts Speed FMT or EDC			
11 Enter 704	Prompts EDC			
12 Enter 1865	Prompts to Block from			
13 Enter STATE	Prompts Track from			
14 Enter 1	Prompts Block to			
15 Enter EVAN	Prompts Track to			
16 Enter STATE	Prompts Origin Block			
17 Enter 1	Prompts Origin Track			
18 Enter 1	Prompts Execute M Or SYS			
19 Enter M				
				No Response
				Enter #5 in Command Menu. To Check Create And Issue

MANUAL TEST PROCEDURE

SUBJECT: 6.8 CHANGE MEET

X704M - AUTH. SPORT TO SSQUAM
X703M - AUTH. SPORT TO SSQUAM
MO 16 - AUTH. STMR 1 TO SPORT

SCENARIO:
CHANGE MEET X703M AND MO 16 TO PORTEAU
MO 16 LEAVE STMR 1 ARRIVAL X704M

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
Create X704M SPORT 0 to SSQUAM 0 Issue X704M SPORT 0 to SSQUAM 0				Double white then double yellow SPORT 0 to SSQUAM No response
Create X703M SPORT 0 to SSQUAM 0 Issue X703M SPORT 0 to SSQUAM 0				Double white then double yellow STMR 1
Create MO 16 STMR 1 TO SPORT 0 Issue MO 16 STMR 1 to SSQUAM 0 Issue MO 16 STMR 0 to SPORT 0				Arrow ID appears in STMR 0. Track returns to single white then goes to double white for X703M SPORT 0 to SSQUAM 0
Enter X704M STMR 0 Clear X704M SSQUAM 0				Double yellow SPORT 0 to SSQUAM 0
Send AUTH X703M SPORT 0 to SSQUAM 0 Use Cancel Menu Cancel Issue X703MSPORT 0 to SSQUAM 0				
Enter 6 Enter X703M Enter 1 Cancel Issue Menu appears cursor flashing at Execute field Use up arrow to enter fields and "DO" command to delete Change "BLK FROM" to POST	Cancel Menu Prompt Name Prompt Create or Issue			
Enter space bar (to underline) Enter Grant Enter Return				POST 0 to SSQUAM 0 goes to double yellow. Request change of authority appears. Prompt underline Prompt Grant or Decline Prompt Return for Current Time Prompt Return Track to double white for MO 16 Double white, double yellow
Issue X703MSPORT 1 to POST 1 Issue X703M SPORT 0 to SSQUAM 0				
Manually enter MO 16 into PORT 0 Manually clear MO 16 SPORT				MO arrow appears in PORT Track goes to double white POST to SSQUAM for X703M AUTH.
Enter X703M Manually into SSQUAM Clear X703M SSQUAM				MO arrow in SSQUAM Track clears and AUTH for MO 16 at SPORT comes to double white.

MANUAL TEST PROCEDURE

SUBJECT: A.O.M.O.V. AUTHORITY, ONE FOREMAN

SCENARIO: ISSUE M.O.V. AUTHORITY TO FOREMAN JONES BETWEEN BRUM AND SPORT

DISPATCHER INPUT	COMMAND Menu DISPLAY	MANUAL GRAPHICS DISPLAY	TRACE GRAPHICS DISPLAY	COMMENTS
1 Enter I	Prompt Name			
2 Enter Jones	Prompt Type			
3 Enter M	Prompt ID			
4 Enter Time	Prompt DIR			
5 Enter 8	Prompt Speed			
6 Enter M1	Prompt Cab			
7 Enter M1	Prompt Engineer			
8 Enter M1	Prompt Block from			
9 Enter BRUM	Prompt Track from			
10 Enter O	Prompt Block to			
11 Enter SPORT	Prompt Track to			
12 Enter O	Prompt Origin Block			
13 Enter BRUM	Prompt Origin Track			
14 Enter O	Prompt Execute			
15 Enter M				
16 Enter 2	Prompt Name			
17 Enter Jones	Prompt DIR			
18 Enter 8	Prompt Type			
19 Enter E	Prompt Block from			
20 Enter BRUM	Prompt Track from			
21 Enter O	Prompt Block to			
22 Enter SPORT	Prompt Track to			
23 Enter O	Prompt Execute			
24 Enter Y				
25 Enter M	Prompt Type			
26 Enter Jones	Prompt Foreman			
27 Enter 203	Prompt Can			
28 Enter Time	Prompt 203			
29 Enter Underline	Prompt Underline			
30 Enter Return	Prompt for Current Time Return			
31 Enter Return	Prompt Return			
			Double White BRUM to SPORT	
			Double Yellow BRUM SPORT	
				Should default After time Entered to Block from

MANUAL TEST PROCEDURE

SUBJECT: 6.10 REMOVE M.O.V.

SCENARIO: REMOVE M.O.V. AUTHORITY FROM FOREMAN JONES BETWEEN BRUN AND SPORT

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
---------------------	-------------------------	----------------------------	---------------------------	----------

A Issue Authority as per Scenario 6.9 - BRUN 0 to SPORT 0

1	Enter 4	Prompt Name		
2	Enter Jones	Prompt Type		
3	Enter 1			
4	Change Block from in Cancel Issue Menu	Prompt Execute		
5	to BRUN Enter Y			
6	Enter Space Bar to Underline			Prompt Underline for Issue Cancellation
7	Enter 6			Prompt Grant or Decline
8	Enter 3	Prompt Name		
9	Enter Jones	Prompt C or I		
10	Enter C	Prompt Execute		
11	Use Up Arrow to go to Block from Enter Do Key Enter BRUN Enter Y	Prompt Execute		
12	Enter 4	Prompt Name		
13	Enter Jones	Prompt C.I.I.		
14	Enter 1			

BRUN to SPORT goes
to Single White

No Response

Graphics Return to Single
White at BRUN

MANUAL TEST PROCEDURE

SUBJECT: 6.11 CLEAR TRAIN THROUGH MOW

SCENARIO: FOREMAN JONES HOLDS MOW AUTHORITY BETWEEN BRUM AND SPORT, NO 3 AUTH NVAN - MSQUAM

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1	Create Jones BRUM to SPORT				
2	Issue Jones BRUM to SPORT				
3	Create No. 3 NVAN to MSQUAM				
4	Issue No. 3 NVAN to MSQUAM				Double White NVAN to SRUM Double Yellow NVAN to SRUM
5		(RBE) Request Block Entry Jones		No. 3 10 in White in BRUM Block	
6		(BEA) Block Entry Authority		No. 3 10 in Yellow BRUM Block	
7	Repeat of 5 and 6 for each of Jones' Blocks				
8		BEA for PORT to MSQUAM No. 3		Double White PORT to MSQUAM for No. 3	
					Double Yellow PORT to MSQUAM No. 3

MANUAL TEST PROCEDURE

6-12 JOINT AUTHORITY FOR TWO WORK EXTRAS

SUBJECT:

SCENARIO: ISSUE JOINT AUTHORITY FOR WX 723 AND WX 722 BETWEEN NVAN AND SBRUM

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1 Enter 1	Prompt Name			
2 Enter WX723	Prompt Type			
3 Enter 1	Prompt STD			
4 Enter 1000	Prompt DIR			
5 Enter 8	Prompt Speed			
6 Enter f	Prompt Engineer			
7 Enter 723	Prompt Cab			
8 Enter 1845	Prompt Block from			
9 Enter NVAN	Prompt Track from			
10 Enter 0	Prompt Block to			
11 Enter SBRUM	Prompt Track to			
12 Enter 0	Prompt ORG Block			
13 Enter NVAN	Prompt ORG Track			
14 Enter 0	Prompt Men, Sys or No			
15 Enter M				
16 Enter 2	Prompt Name			
17 Enter WX723	Prompt DIR			
18 Enter 8	Prompt Type			
19 Enter E	Prompt Block from			
20 Enter NVAN	Prompt Track			
21 Enter 0	Prompt Block to			
22 Enter SBRUM	Prompt Track to			
23 Enter 0	Prompt Execute			
24 Enter 1				Double White NVAN to SBRUM
25 Enter 1	Prompt Type			
26 Enter Name	Prompt Conductor			
27 Enter Name	Prompt Engineer			
28 Enter Time	Prompt Time			
29 Enter Space Bar	Prompt Underline			
30 Enter Return	Prompt Return			Double Yellow NVAN to SBRUM
31 Repeat Lines 1 through 15 substituting WX722 for Cab 1845				
32 Repeat Lines 16 through 23 substituting in Line 19 Enter J				
33 Repeat Lines 16 through 23 substituting in Line 19 Enter J				
34 Repeat Lines 16 through 23 substituting in Line 19 Enter J				
35				ID WX722 in White in NVAN Block ID in Yellow NVAN Block

MANUAL TEST PROLOGUE

SUBJECT: 6.13 - CHANGE UNIT

SCENARIO: CHANGE LEAD UNIT ON NO 3 AT RVAN FROM PC30 TO BC31. NO1 HAS BEEN C AND HAS EXCLUSIVE AUTHORITY RVAN TO SYNTR

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS

MANUAL 1131 PROCEEDURE

SUBJECT: 6.14 TWO TRAINS MEETING IN NOW LIMITS

SCENARIO: MAKE TWO TRAINS MEET IN NOW LIMITS - NOW LIMITS IN EFFECT S.BRUM AND SPORT - NO 1 NVAM TO STAIR - 1 AND ISSUED NVAM TO SNET

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1	Create	No 1 NVAM to STAIR - 1			
2	Issue	No 1 NVAM to SNET			Double White
3	Create	No 16 SQUAM to NVAM			Double Yellow
4	Issue	No 16 SQUAM to PORT			Double White
5	Create	NOW SBRUM to SPORT			Double Yellow
6	Issue	NOW SBRUM to SPORT			Double White
7	Issue	No 1 SBRUM 0 SBRUM 1			Double Yellow
8		RBC	No 1 from SBRUM 0 to SBRUM 0		ID in White SBRUM
9		SEA	No 1 SBRUM 0 to SBRUM 0		ID in Yellow SBRUM
10		RBE	No 1 SBRUM 1 to SBRUM 1		ID in White SBRUM 1
11		SEA	No 1 SBRUM 1 to SBRUM 1		ID in Yellow SBRUM 1
12	Repeat	STEPS 8 thru 11 for No 16 in Blocks			
13	Issue	SPORT thru SBRUM			
14		No 1 SBRUM to SQUAM			
15		Block Entry			
16	Repeat	Block Clear			
		No 8 through No 16 for No 1	for No 16 SBRUM 0 PFI		No 1 ID in White SBRUM
			No 16 SBRUM 0		SBRUM to SPORT

o RBC - Request Block Entry
so SEA - Block Entry Authority

MANUAL TEST PROCEDURE

SUBJECT: 6.15 TWO TRAINS MEETING IN JOINT LIMITS (FOUR TRAINS ONE BLOCK)

SCENARIO: WX723 AND F-1MAN JONES JNT AUTH SERUM AND MPORT, MEETING NO 1 AND NO16 AT BRUM, NO 1 TAKE SIDING
NO 1 AUTH NVAN SSET NO16 AUTH SQUAM - BRIT.

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1	Create WX 723	SERUM 0	to MPORT 0		
2	Issue WX 723	SERUM 0	to MPORT 0		
3	Issue WX 723	0 to BRUM 0	to SPORT 0		
4	Issue WX 723	PORT A to MPORT	SEA WX 723 SERUM	Double White SERUM	
5			SEA WX 723 SERUM A	Double Yellow SERUM	
6			SEA WX 723 SERUM A	Double White SERUM A	
7			SEA WX 723 SERUM A	Double White MBRUM to SPORT	
8			to SPORT	Double Yellow MBRUM to SPORT	
9			SEA WX 723 PORT	Double White PORT A	
10	Repeat	1 thru 9 for F-1man Jones plus MRE for 5 thru 9 Note: MRE and SEA have to be done for each Block individually	SEA WX 723 MPORT	Double White MPORT	
11				Jones 10 Yellow	
12				Blocks SERUM to MPORT	
13	Create No 16	SQUAM to NVAN			
14	Issue No 16	SQUAM to BRIT			
15		Issue No 1	SERUM 0 to BRUM 1	Double White - SQUAM to BRIT	
16		MRE No 1	SERUM 0 - Foreman Jones	Double Green - SQUAM to BRIT	
17		MRE No 1	SERUM 0 - WX723		
18		SEA No 1	SERUM 0	10 White Multi SERUM	
19	Repeat of Line 15 to 19 - BRUM 1			10 Yellow Multi SERUM	
20	Issue	No 16 MPORT to BRUM		10 White Multi BRUM 1	
21		MRE No 16	MPORT 0 - Foreman Jones	10 Yellow Multi BRUM 1	
22		SEA No 16	MPORT 0 - WX723	10 White MPORT Multi	
23		SEA No 16	MPORT 0	10 Yellow MPORT Multi	

Repeat of Line 21 to 23 - PORT, SPORT DEELS, MBRUM and BRUM

MANUAL 11.1 PRODUCTIONS

SUBJECT: 6.16 ONE TRAIN OVERTAKES ANOTHER TRAIN

SCENARIO: NO 1 PASS EXTRA 721 NORTH AT BRUM, NO 1 GO THROUGH SIDING

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1	Create No 1	MAN 0 - STMT - 1			
2	Issue No 1	MAN 0 - MSAY - 0			Double White Double Yellow
3	Create	X721 M	MSSET 0 to MS		Double White
4	Issue	X721 M	MSSET 0 to MSQUAM		Double Yellow
5	Issue No 1	MSSET 0 to SBUM 0			Joint Auth.
6	Issue No 1	BRUM 1 to BRUM 1			Excl. Auth.
7		SEE	X721M - for No 1 Enter MSSET	No 1 ID White MSSET	
8		SEA	No 1 Enter MSSET	No 1 ID Yellow MSSET	
9	Repeat 7 and 8 for SBUM				
10		SEA	No 1 BRUM	Double White BRUM 1	
11	Issue No 1	MSBPM 0 to SSQUAM			Double Yellow
12	Issue No 1	STMT - 1 to STMT - 1			Double White
13	Issue X721M	MSBPM 0 to MSQUAM 0			Double Yellow
14		RBE No 1	X721M Enter MSBPM	X721 M ID in White MSBPM	
15		SEA No 1	X721M Enter MSBPM	X721 M ID in Yellow MSBPM	

Repeat 14 and 15 for each block until MS 1 able to clear blocks ahead of X721M

MANUAL TEST PROCEDURE

SUBJECT: 6.17 SAW BY UTM 2 TRAIN MEET

SCENARIO: NO 23 AND NO. 16 MEET AND SAW BY AT BRUM

	DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACE GRAPHICS DISPLAY	COMMENTS
1	Create No 23				
2	Issue	SWST to NSOURN NO 23 SWSET 0 to SWSET 0		Double White Double Yellow	
3	Create				
4	Issue	NO 16 DEERS TO NVAH NO 16 DEERS 0 to DEERS 0		Double White Double Yellow	
5	Issue	NO 23 BI AUTH. SERUM TO BRUM A		Double White Double Yellow	
6	Issue	NO 23 BI AUTH NBRUM		Double White Double Yellow	
7	Issue	NO 16 AUTH BI JET NBRUM - BRUM A		Double White Double Yellow	
8	Issue	NO 16 AUTH BI JET - SERUM		Double White Double Yellow	
9	R BE	NO 23 for NO 16 Enter NBRUM		Double White Double Yellow	
10	SEA	NO 16 Enter NBRUM		Double White Double Yellow	
	Repeat lines 9 and 10 for Blocks BRUM and SERUM				

MANUAL TEST PROCEDURE

SUBJECT: 6.18 REVISE DESTINATION

SCENARIO: CHANGE DESTINATION AND EXPECTED DEPARTURE TIME
721 W DEST PORT INSTEAD OF SQUAM

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
---------------------	-------------------------	----------------------------	---------------------------	----------

Create N721N RVAN 0 to W SQUAM 0

Revise Create N721 North PORT 0 to W SQUAM 0

Change Time

Cancel Create N721 North WPORT 0

MANUAL TEST PROCEDURE

SUBJECT: 6.10 RUN LITE ERG TO ASSIST DISABLED TRAIN

SCENARIO: NO 23 CREATED NVAN TO SSQUAM NO 23 DISABLED AT PORT RUN LITE SSQUAM TO PORT TO ASSIST NO 23 PORT TO SSQUAM

DISPATCHER INPUT	COMMAND MENU DISPLAY	MANUAL GRAPHICS DISPLAY	TRACK GRAPHICS DISPLAY	COMMENTS
1 Create NO 23	NVAN to SSQUAM			
2 Issue NO 23	NVAN to SSQUAM			
3 Create	X 701S SSQUAM to PORT			
4 Issue	X 701S SSQUAM to PORT			Double White Double Yellow
5 Cancel	Issue NO 23 MPORT to SSQUAM			
6 Issue	Auth X 701 SSQUAM to MPORT			Double Yellow back to Single White Double White SSQUAM to MPORT Double Yellow
7 RUC	X 701S to Enter PORT			10 X 701S PORT in White 10 X 701S Yellow in PORT
8 BEA	X 701S PORT			
9	Enter X701S PORT	PRG		
10	Clear X701S MPORT	Track Clear		
11	When X 701S arrives into PORT			
12 Issue	NO 23 MPORT to SSQUAM	Cancel X701S		Double White Double Yellow

APPENDIX D

List of Host Sub-system Messages
and Abbreviations

Definition of Terms

Host System Messages:

(ALN) - Assign Logical Name

A logical name is assigned to a train in the system.

(ARBE) - Authority Response for Block Entry

If a train is requesting to enter a block which is currently owned by another train a response from the train who owns the block is received via this message.

(ARRI) - Authority Response to Recanted Issued Authority

If a train's issued authority is to be cancelled a response from this train is received via this message.

(ARRN) - Authority Response to Recant with New Authority

A train's issued authority is to be changed; the response from the train is received via this message.

(BEA) - Block Entry Authority

A train is issued authority to enter a block(s).

(CIA) - Conflict with Issued Authority

A train has detected a conflict with its issued authority. For example, a train receives a BEA which conflicts with a previous BEA.

(ECM) - Emergency Check Message (not fully implemented)

A train is in an emergency situation or is detected as being in an emergency (unsafe condition).

(RBE) - Request for Block Entry

A train is requesting to enter a block currently owned by another train or system member.

(RIA) - Recent Issued Authority

A train's issued authority is to be cancelled.

(RNA) - Recent With New Authority

A train's issued authority is to be changed.

(RVP) - Request Virtual Path

A command required by the network manager, used to establish communications with a given train or other mobile device.

(CANTRN) - Cancel Train

A train is cancelled. Remove all data in respect to that train from the system's data base.

(SCH) - Status Change Message

The block position of a train has changed.

(TEXTN) - Text

A portion, (8 characters) of a text message sent to a train.

(UCI) - Update Control Information

Command to update the system's data base.
(not yet implemented)

(CANCRE) - Cancel Create

A train previously created is cancelled.

(CANISS) - Cancel Issue

A train's previously issued authority is cancelled.

(CREATE) - Create

A train is supplied to the system.

(ISSUE) - Issue

A train is issued an authority.

(RVSCRE) - Revise Create

A train's previously created limits are revised.

(RVSISS) - Revise Issue

A train's previously issued authority is revised.

(RVSLN) - Revise Logical Name

A logical name previously assigned to a train is revised.

(TEXT0) - Text

The beginning portion (8 characters) of a text message sent to a train.

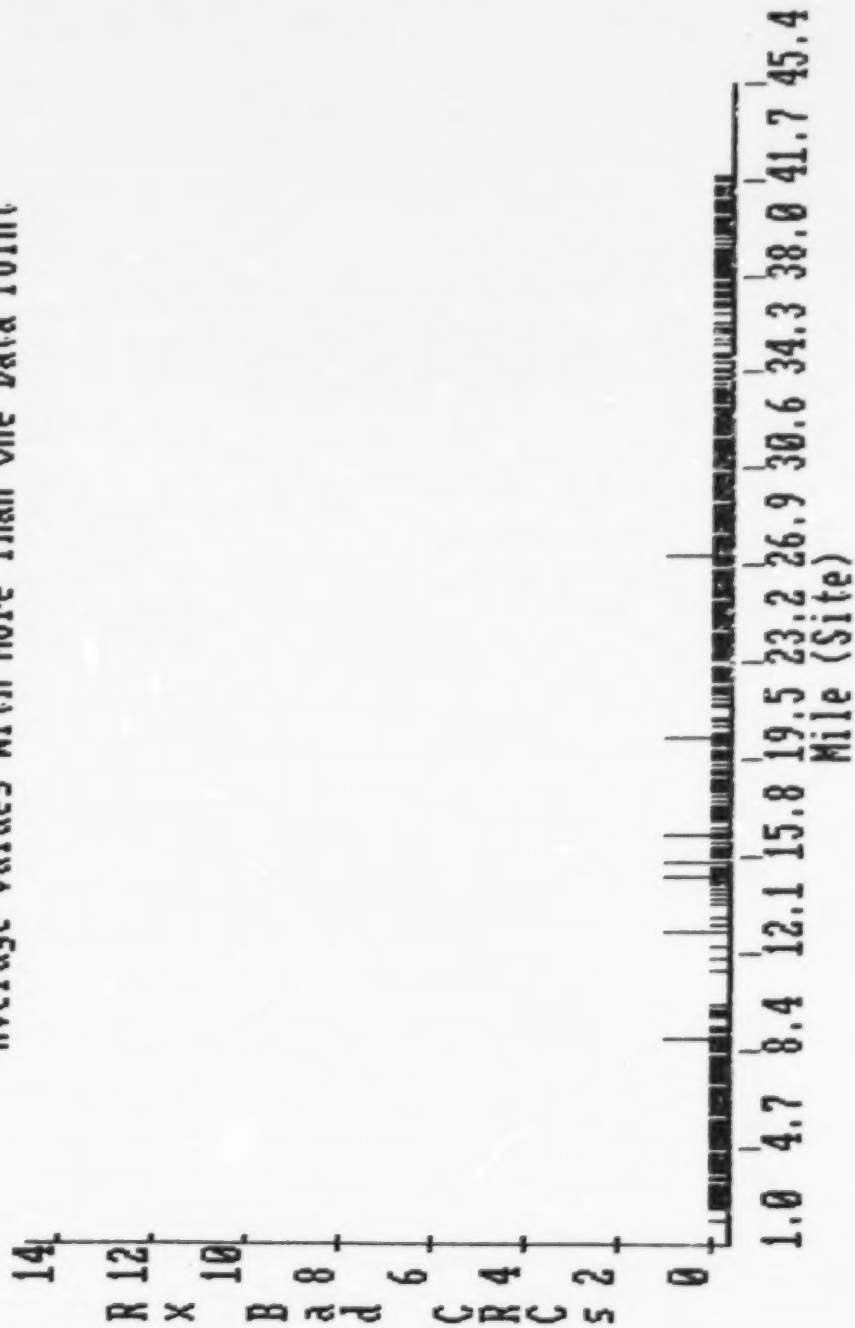
APPENDIX E

Set of Six Typical Signal-quality Histograms

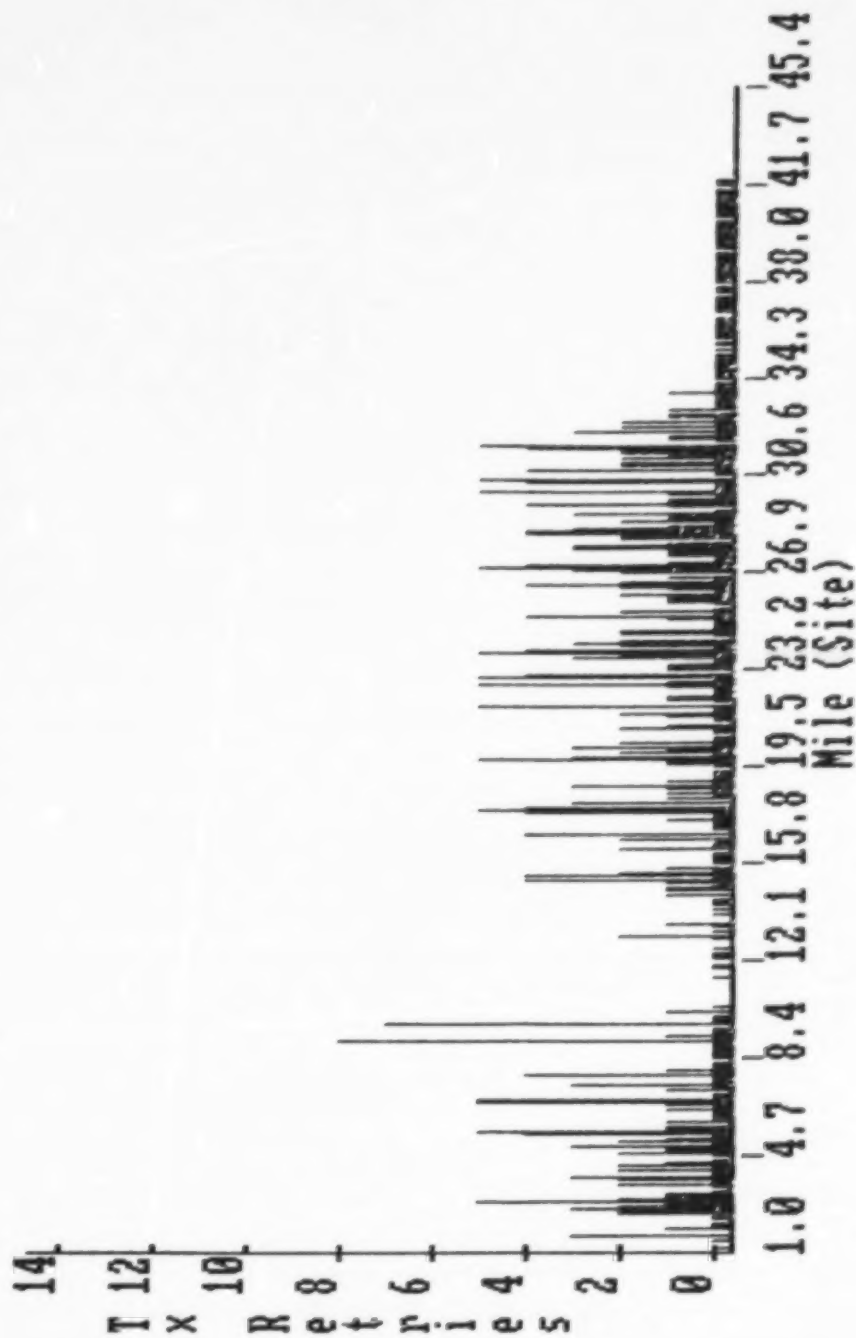
Transmitter Retries (Average Value) vs Mile Average Values With More Than One Data Point



Receiver CRC Errors (Average Value) vs Mile Average Values With More Than One Data Point



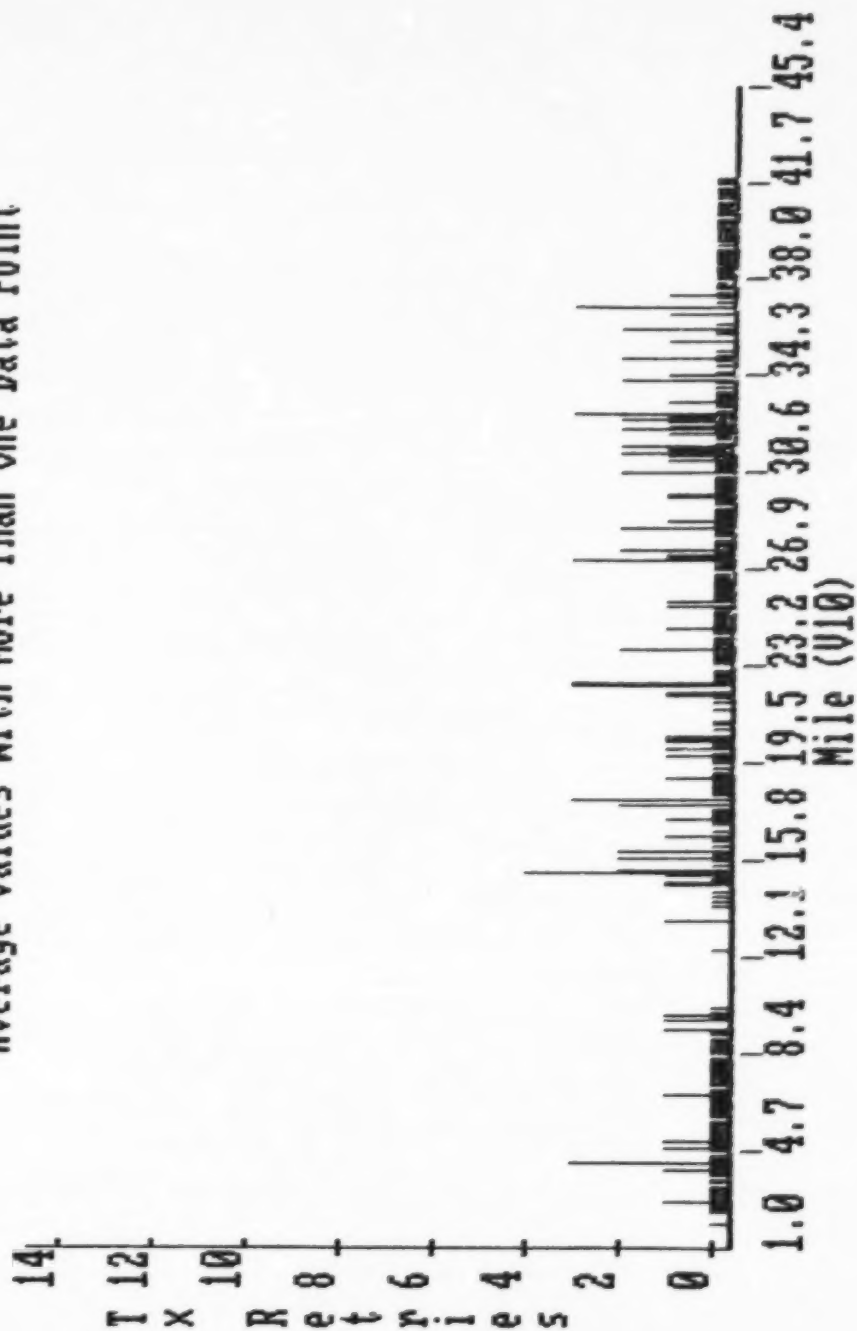
Transmitter Retries (High Value) vs Mile



Receiver CRC Errors (Average Value) vs Mile Average Values With More Than One Data Point



Transmitter Retries (Average Value) vs Mile Average Values With More Than One Data Point



Transmitter Retries (High Value) vs Mile

